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THE UNIVERSITY OF ALBERTA

Effect of Hypolimnetic Oxygenation on the Phytoplankton Community of Deep, Eutrophic Amisk Lake, Alberta

by

Deborah Jean Webb

A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH

IN PARTIAL FULFILMENT OF THE REQUIREMENTS OF THE DEGREE

OF MASTER OF SCIENCE

DEPARTMENT OF ZOOLOGY

EDMONTON, ALBERTA

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research, for acceptance, a thesis entitled Effect of Hypolimnetic Oxygenation on the Phytoplankton Community of Deep, Eutrophic Amisk Lake, Alberta, submitted by Deborah Jean Webb in partial fulfilment of the requirements for the degree of MASTER OF SCIENCE.

Supervisor

ABSTRACT

Amisk Lake is a eutrophic two-basined lake where hypolimnetic water was oxygen-poor. Oxygen was injected into the shallower basin of the lake, and the phytoplankton community and chlorophyll *a* concentration ([Chl *a*]) were monitored during the first two open-water seasons (1988 and 1989) of hypolimnetic oxygenation. With respect to the effect of treatment on the phytoplankton, the following hypotheses were tested: 1) hypolimnetic oxygenation will result in a decrease in mean [Chl *a*] during the open-water season; 2) hypolimnetic oxygenation will result in lower [Chl *a*] in the treated basin than in the untreated basin; 3) Chl *a* will be distributed deeper in the water column as a result of treatment; and 4) dominant phytoplankton species will shift from cyanobacteria throughout the open-water season to green algae for at least a portion of the time.

To select an appropriate method for [Chl *a*] measurement for the oxygenation study, and to establish if [Chl *a*] should be corrected for the presence of phaeopigments (Pha), Chl *a* in samples from three mesotrophic to eutrophic lakes (Long, Narrow and Island lakes) in north-central Alberta was extracted with one of three solvents (95% ethanol, 90% ethanol, or a 2:3 mixture of dimethyl sulfoxide and 90% acetone (DMSO/acetone)) and analyzed by two techniques (spectrophotometry in 1986 and 1989, and high performance liquid chromatography (HPLC) in 1989). Based on 1986 results, [Chl *a*] in Amisk Lake during 1988 and 1989 was determined by spectrophotometric analysis of ethanol extracts; since a large proportion of total [Chl *a*] appeared to be Pha in the 1986 samples (46% (±8%)), a distinction was made between active [Chl *a*] and [Pha] in Amisk Lake samples. However, HPLC analyses performed on samples collected in July 1989 suggested that although spectrophotometrically determined [Pha] may represent trends in [Pha], the accuracy of these concentrations was questionable. These trends indicated that the proportion of Pha in total [Chl *a*] was related to vertical stability of the water column, species composition of the phytoplankton community and the general health of the phytoplankton. Because [Pha] were unreliable, and also because historic measurements

of [Chl *a*] in Amisk Lake were not corrected for [Pha], total [Chl *a*] were used to determine the impact of hypolimnetic oxygenation on [Chl *a*] and the phytoplankton community.

Historically, mean summer [Chl *a*] and total phosphorus concentration ([TP]) in the upper 6 m of the water column were 17 (±2) and 32 (±2) $\mu g \cdot L^{-1}$, respectively, indicating a eutrophic lake. In 1988 and 1989, mean summer [Chl *a*] in this stratum was 10 and 8 $\mu g \cdot L^{-1}$, respectively, and mean summer [TP] was 29 and 22 $\mu g \cdot L^{-1}$, respectively, indicating that the trophic status of Amisk Lake had shifted towards mesotrophy. Prior to treatment, Chl *a* was concentrated in the upper 6 m of the water column, and the depth of the euphotic zone was approximately the same as that of the epilimnion. In 1988 and 1989, the euphotic zone extended below the epilimnion throughout most of the open-water season, enabling phytoplankton to grow at depths in the metalimnion and upper hypolimnion on a number of dates. The greatest impact of treatment on the phytoplankton community appeared to be the extended period of deep mixing of the water column in spring that accompanied hypolimnetic oxygenation. Turbulence throughout the entire water column in spring 1989 provided favourable conditions for an extended diatom bloom (*Asterionella formosa* and *Cyclotella* spp.), followed by a delay in the development of the summer cyanobacterial community (*Aphanizomenon flos-aquae* and *Anabaena flos-aquae*).

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Table of Contents

Chapter		Page
	Abstract	iv
	Acknowledgements	vi
	List of Tables	x
	List of Figures	xi
1.	General Introduction	1
	1.1 References	10
2.	Comparison of chlorophyll *a* extractions with ethanol and dimethyl sulfoxide/acetone, and a concern about spectrophotometric phaeopigment correction	17
	2.1 Introduction	17
	2.2 Methods and Materials	18
	2.3 Results	21
	2.4 Discussion	23
	2.5 References	27
3.	Spectrophotometrically determined phaeopigment patterns in Amisk Lake	34
	3.1 Introduction	34
	3.2 Methods and Materials	35
	3.3 Results	37
	3.4 Discussion	39
	3.5 References	44
4.	Influence of extended water column mixing in spring on the phytoplankton community in "naturally" eutrophic Amisk Lake, Alberta	52
	4.1 Introduction	52
	4.2 Background and Methods	54
	4.3 Results	61
	4.4 Discussion	69

4.5 References 76
5. General Discussion 96
5.1 References 101
6. Appendix - Data 104

LIST OF TABLES

Table		Page
2.1	Mean concentrations of phaeopigment-corrected chlorophyll *a*, phaeopigments and total chlorophyll *a* from three solvents and two techniques in water samples collected from three mesotrophic to eutrophic Alberta lakes	31
3.1	Mean proportions of spectrophotometrically determined phaeopigments in total chlorophyll *a* concentrations in Amisk Lake, 1988 and 1989	46
4.1	Ranges of historical mean summer (June - August) data from Amisk Lake	82
4.2	Summary of coefficients of variation in total chlorophyll *a* concentrations between pairs of replicate samples	83
4.3	Mean nutrient concentrations, 1988 and 1989	84
4.4	Summary of analyses of variance (three-factor ANOVA's: date x depth x site) of total chlorophyll *a* concentrations, 1988 and 1989	85
4.5	Summary of mean total chlorophyll *a* concentrations over time	86
4.6	Summary of multiple comparisons (Student-Newman-Keuls tests) of mean total chlorophyll *a* concentrations from all sampling depths among dates	87
4.7	Phytoplankton taxa identified in Amisk Lake samples, 1988 and 1989	88
4.8	Percentage composition of total phytoplankton biovolume by major phytoplankton groups and total chlorophyll *a* concentrations, 1988	89
4.9	Percentage composition of total phytoplankton biovolume by major phytoplankton groups and total chlorophyll *a* concentrations, 1989	90

LIST OF FIGURES

Figure		Page
2.1	Composite HPLC chromatogram of chlorophyll *a* and *b* and phaeophytin *a* and *b*	32
2.2	HPLC chromatogram of DMSO/acetone extract (solid line) and 90% ethanol extract (dotted line) of samples taken from Island Lake at a depth of 5.5 m	33
3.1	Amisk Lake, Alberta	47
3.2	Vertical profiles of water temperature and percent phaeopigments in total chlorophyll *a* concentration in Amisk Lake, 1988	48
3.3	Vertical profiles of water temperature and percent phaeopigments in total chlorophyll *a* concentration in Amisk Lake, 1989	49
3.4	Chlorophyll *a* (corrected for phaeopigments) and phaeopigment concentrations at each sampling depth in Amisk Lake during 1988 and 1989	50
3.5	Phytoplankton biovolume in the epilimnion and metalimnion of Amisk Lake, 1988 and 1989	51
4.1	Amisk Lake, Alberta	91
4.2	Vertical profiles of water temperature, total chlorophyll *a* concentration (not corrected for phaeopigments), and depth of euphotic zone in Amisk Lake, 1988	92
4.3	Depths of epilimnion and euphotic zone during the thermally stratified period in Amisk Lake, 1988 and 1989	93
4.4	Vertical profiles of water temperature, total chlorophyll *a* concentration (not corrected for phaeopigments), and depth of euphotic zone in Amisk Lake, 1989	94
4.5	Nutrient concentrations in the epilimnion, metalimnion, and mid-hypolimnion in Amisk Lake, in 1988 and 1989	95

1. General Introduction

Phytoplankton are an important component in aquatic ecosystems. Through the process of photosynthesis, phytoplankton convert light energy to chemical energy via the following basic equation:

$$6\ CO_2 + 12\ H_2O \xrightarrow[\text{photosynthetic pigments}]{\text{light}} C_6H_{12}O_6 + 6\ H_2O + 6\ O_2 \qquad (1.1)$$

The organic matter that is produced, along with other macro- and micronutrients that the phytoplankton incorporate into their cell components from the water, is available for consumption and use by higher trophic levels, such as zooplankton, benthic invertebrates, and fish. The presence of phytoplankton in sufficient quantity (number of cells, biovolume) and quality (species desirable as a food source by zooplankton) is important to sustain a diverse aquatic community.

Measurement of Chlorophyll a

Measurement of chlorophyll *a* concentration ([Chl *a*]) is a standard, internationally accepted, routine method for evaluating trophic status of aquatic systems. Generally, lakes in which [Chl *a*] ranges between 0 and 3 $\mu g \cdot L^{-1}$ are classified
as oligotrophic, between 2 and 15 $\mu g \cdot L^{-1}$ as mesotrophic, and between 10 and 500 $\mu g \cdot L^{-1}$ as eutrophic to hyper-eutrophic (Wetzel 1983). The trophic categories are not exact and involve some subjectivity in the overlap areas.

The accuracy of [Chl *a*] measurements depends to a great extent on the solvent used for extraction and on the technique used for analysis. Extraction of Chl *a* with acetone is widespread (Richards and Thompson 1952; Moss 1967; Strickland and Parsons 1972; Daemen 1986), particularly for marine phytoplankton. However, the

extraction efficiencies of methanol, ethanol, and combinations of dimethyl sulfoxide and 90% acetone are often superior to that of acetone for most green algae and some cyanobacteria (blue-greens), particularly freshwater species (Shoaf and Lium 1976; Holm-Hansen and Riemann 1978; Stauffer et al. 1979; Burnison 1980; Sartory and Grobbelaar 1984; Jespersen and Christoffersen 1987). Spectrophotometric and fluorometric techniques yield higher [Chl *a*] than high pressure liquid chromatography (HPLC) due to their erroneous measurement (and inclusion) of pigments and degradation products other than Chl *a* (Mantoura and Llewellyn 1983; Sartory 1985; Daemen 1986; Murray et al. 1986; Jacobsen and Rai 1990; Neveux et al. 1990). Therefore, choice of technique and choice of a solvent appropriate for the phytoplankton species present can have a significant impact on resulting [Chl *a*] measurements.

Contribution of Phaeopigments to Total [Chl a]

Distinction between active Chl *a* and degraded Chl *a* (i.e., phaeopigments) may affect the accuracy of [Chl *a*] measurements in situations where phaeopigments (Pha) are expected to contribute a large proportion of the total [Chl *a*]. High proportions of Pha may occur in water exposed to high irradiance (Lorenzen 1967), within the aphotic zone (Yentsch 1965), in regions of heavy zooplankton grazing (Glooschenko et al. 1972; Carpenter and Berquist 1985), and after the collapse of a phytoplankton bloom (Nusch 1980).

The proportion of total [Chl *a*] made up of Pha varies greatly between studies. In samples collected from a depth of 1 m in eutrophic, polymictic Kinnego Bay (Lough Neagh, N. Ireland), Pha was rarely greater than 10% of total [Chl *a*] (Jones 1977a). In deep, mesotrophic Pluss See (north Germany), Pha contributed > 50% of total [Chl *a*] at all depths from 0 to 25 m, with maximum active [Chl *a*] found within the euphotic zone, and maximum [Pha] usually in the region of the thermocline near the bottom of the euphotic zone (Rai 1975). Finally, in pooled samples collected from depths of 1 and 5 m in mesotrophic Lake Ontario, Pha contributed anywhere from 0 to

100% of total [Chl *a*] (Glooschenko et al. 1972). However, the need for distinction between active [Chl *a*] and [Pha] may depend on the questions being addressed in a given study: in some situations (for example, determination of potential food resources for zooplankton), measurement of total [Chl *a*] may be more appropriate than measurement of active [Chl *a*].

Factors Affecting Succession of Phytoplankton Species in Eutrophic Temperate Lakes

In temperate eutrophic lakes, dominance in the phytoplankton community typically shifts from diatoms and cryptophytes to green algae to cyanobacteria and then often back to diatoms as the open-water season progresses (Wetzel 1983; Reynolds 1984). This same pattern has been reported in southern hemisphere reservoirs, with a return to cyanobacterial dominance with restratification during the winter season (Ashton 1985). Shifts in dominance from one group to another have been attributed to the different abilities of the various phytoplankton to cope with and/or adapt to changes in physical, chemical and biological parameters in the surrounding environment through time.

Increasing irradiation and temperatures in spring, combined with higher nutrient concentrations that accompany turbulent conditions in the water column, promote growth of fast-growing, small-celled species (i.e., "r-strategists"), such as diatoms, cryptomonads, small green algae and nannoflagellates (Lund 1950a; Holligan and Harbour 1977; Jones 1977b; Porter 1977; Ashton 1985; Reynolds et al. 1987). These smaller cells may have a competitive advantage under such conditions by having faster nutrient-uptake rates than larger cells, due to their high ratio of absorptive surface to cell volume (Friebele et al. 1978; Wetzel 1983). Diatoms are superior competitors for phosphorus than green algae and cyanobacteria, as long as silicon and nitrogen are present in sufficient concentrations, and diatoms have a lower requirement for phosphorus than do green algae (Keating 1978; Kilham 1986). Diatoms also grow better at low temperatures than do green algae or cyanobacteria (Tilman et al. 1986). Turbulence within the water column is particularly important to diatom populations, which rely on external forces in order to remain in the euphotic zone: once the water

column is thermally stratified, diatom cells which settle out of the epilimnion cannot return and thus descend to the lake bottom (Lund 1971; Knoechel and Kalff 1975; Reynolds 1975; Kalff and Knoechel 1978; Trimbee and Harris 1984; Jewson et al. 1981; Gray 1987). Small size is advantageous to diatoms in reducing the settling rate of the cells (Wetzel 1983). However, the physical and chemical environment in a lake is dynamic: conditions that favour diatoms are often only temporary, and the spring diatom bloom collapses.

As summer approaches, light intensity and temperature continue to increase. Increasing irradiance may lower production rates of diatom populations during later stages of spring growth (Titman and Kilham 1976; Neale et al. 1991). Studies have indicated that *Asterionella* sp., *Cyclotella* sp. and *Scenedesmus* sp. populations in stationary growth phase sink four times more rapidly, on average, than cells in populations undergoing exponential growth (Titman and Kilham 1976), and dead *Asterionella* sp. and *Tabellaria* sp. cells sink faster than living cells (Smayda 1974). Thus it becomes more and more difficult for diatoms to remain in the euphotic zone, especially if the lake becomes thermally stratified at this time. Silicon, an essential nutrient for all diatom species, may also become limiting by this time, further reducing the ability of diatoms to remain the dominant phytoplankton (Lund 1950a and 1950b; Kilham 1975; Jones 1977b; Sze 1980; Jewson et al. 1981; Harris 1986; Kilham 1986). In addition to deteriorating physical and chemical conditions, diatoms are also highly vulnerable to grazing pressure by zooplankton, primarily nonselective filter feeders such as cladocerans (which are capable of rapid reproduction in the presence of an abundant food source), *Daphnia* sp. and cyclopoid copepods (Porter 1973 and 1977; Andersson et al. 1978; McCauley and Briand 1979; Lynch and Shapiro 1981; Carpenter and Kitchell 1984; Lampert et al. 1986; Elser and Carpenter 1988; Mazumder et al. 1990; Vanni and Temte 1990).

Phytoplankton that dominate the euphotic zone in summer (such as flagellates, and *Microcystis aeruginosa* and other cyanobacteria) are less susceptible to photoinhibition than spring and winter populations, often due to a reduction in the

amount of Chl *a* in each cell (Harris 1973; Tilzer and Schwarz 1976; Reynolds et al. 1987; Zohary and Robarts 1989). In lakes where thermal stratification separates the light-saturated stratum from the nutrient-rich hypolimnion, as well as in lakes experiencing high-frequency fluctuations in vertical mixing and optical depth, species with the ability to make rapid, buoyancy-adjusted vertical movements will be favoured, and these species tend to be large in size (Reynolds et al. 1987; Spigel and Imberger 1987). By summer, the zooplankton community may shift to slower-grazing copepods with a greater range of selectivity and discriminatory feeding: small, naked green algae, nannoflagellates, cryptomonads and any remaining diatoms are susceptible, leaving colonial and filamentous cyanobacteria and gelatinous green algae (with greater grazing defenses) to dominate the phytoplankton (Porter 1977; Bergquist et al. 1985; Bergquist and Carpenter 1986; Lampert et al. 1986; Vanni and Temte 1990).

As nutrients (such as phosphorus and inorganic nitrogen) within the euphotic zone become limited, cyanobacteria emerge as the dominant phytoplankton. Cyanobacteria have a greater ability for rapid uptake of temporary pulses of phosphorus (such as that excreted by fish) than do green algae, and cyanobacteria have the capacity to store nutrients when present in excess of immediate demands for later use (Reynolds et al. 1987). If nitrogen becomes low relative to phosphorus, cyanobacteria with nitrogen-fixing capabilities may become dominant (Smith 1983). A shift in dominance from green algae to cyanobacteria has also been attributed to an increase in pH: cyanobacteria may be more efficient than green algae at obtaining CO_2 when it is present at lower concentrations (i.e., at higher pH); cyanophage production and lysis of cyanobacteria may be reduced at high pH (Shapiro 1973 and 1984); and, at high pH, the solubility of nutrients such as phosphorus, iron and many trace elements is very low, and cyanobacteria may have a higher affinity for one or more of these nutrients (Goldman 1973). Cyanobacteria have superior mechanisms for buoyancy regulation, and can thus remain at a depth where the available light is most favourable, as well as moving to the nutrient-rich metalimnion when necessary (Wetzel 1983). Some cyanobacteria (for example, *Anabaena minutissima*) may further enhance their dominance of the phytoplankton community be releasing substances that may be

toxic to their competitors and potential consumers (Keating 1978; Reynolds et al. 1987; Vincent 1989).

With the breakdown of thermal stratification in fall, decreasing temperatures and increasing turbulence once again provides conditions that are favourable for diatom growth. However, diatom populations are probably restricted by declining irradiation at this time of the year (Holligan and Harbour 1977).

Factors that may contribute to seasonal succession of phytoplankton are numerous. Not only are relationships among the various physical, chemical and biological parameters complex, but the relative importance of each parameter varies from lake to lake, as well as from year to year within any given lake. Thus it is often difficult to predict with any certainty the effect of a lake treatment, such as hypolimnetic oxygenation, on the phytoplankton community and on the relationships among any or all the factors that control seasonal phytoplankton species succession.

Effect of Hypolimnetic Aeration on Phytoplankton Communities

Hypolimnetic aeration is usually employed to achieve at least one of three objectives: 1) to increase dissolved oxygen concentration ([DO]) in the hypolimnion without disrupting thermal stratification or increasing hypolimnetic temperature; 2) to provide increased habitat and food supply for cold-water fish species; and 3) to decrease internal phosphorus loading by eliminating anaerobic conditions at the sediment-water interface (Cooke et al. 1986). Hypolimnetic aeration may be achieved via mechanical agitation (which involves removal, treatment and return of hypolimnetic water), injection of air (which has been the most popular mode of hypolimnetic aeration), or injection of pure oxygen (hypolimnetic oxygenation) (Cooke et al. 1986). Most treated lakes and reservoirs are eutrophic to hyper-eutrophic, and in many, external loading of phosphorus is significant.

The reported effects of hypolimnetic aeration on phytoplankton communities vary greatly, mostly due to confounding variables. In naturally eutrophic Black Lake (British Columbia), treatment had only a minimal effect on phytoplankton abundance and species composition because of an apparent shortage of micronutrients and lack of

exchange between the epilimnion and hypolimnion during thermal stratification (Ashley 1982). In highly eutrophic Weßlinger See (near Munich, Germany), nutrient release from the sediments was significantly reduced, but treatment increased metalimnetic eddy diffusion of nutrients, resulting in increased biomass of filamentous cyanobacteria (Steinberg and Arzet 1984). In Spruce Knob Lake (West Virginia), hypolimnetic aeration had no direct impact on [Chl *a*] (LaBaugh 1980). In Hemlock Lake (Michigan), the increase in phytoplankton growth immediately after treatment began was attributed, in part, to nutrients associated with leaks in the aeration tower, which introduced nutrient-rich hypolimnetic water into the epilimnion (Fast et al. 1973). Summer epilimnetic [TP] and [Chl *a*] were not consistently different between treated and control enclosures in Lake St. George (Ontario), because surface nutrient loading was similar for both enclosures, and nutrient exchange from the hypolimnion was undetectable (McQueen and Story 1986). Hypolimnetic aeration resulted in a reduction in [Chl *a*], cyanobacterial biomass and total phytoplankton biomass, but an increase in biomass of *Ceratium* sp. (a dinoflagellate) and Chlorococcales (green algae) in two hyper-eutrophic Polish lakes, while in a third lake, treatment resulted in decreased cyanobacterial and total biomass, but green algal biomass remained high and unchanged (Simm 1991). In Lake Baldegg (Switzerland), the relative proportion of cyanobacteria has increased since treatment began (Bürgi and Stadelmann 1991). With such a range of potential results, it was impossible to predict the effect of hypolimnetic oxygenation on the phytoplankton community of a naturally eutrophic, oxygen-poor lake in central Alberta.

Framework of Thesis

The goal of this research was to assess the impact of hypolimnetic oxygenation on the phytoplankton community of Amisk Lake, the site of the first whole-lake hypolimnetic oxygenation study in Canada. The main objective of hypolimnetic oxygenation treatment of Amisk Lake was to increase the habitat available to cold-water sport fish; a secondary objective was to decrease internal phosphorus loading from hypolimnetic sediments by reducing/eliminating anoxic conditions at the

sediment-water interface. Historically, Amisk Lake was considered eutrophic (mean [Chl *a*] = 17 (±2) $\mu g \cdot L^{-1}$; Prepas 1990). A decrease in [Chl *a*] would indicate that internal phosphorus loading had been sufficiently reduced by hypolimnetic oxygenation to impact the phytoplankton community. Selection of a suitable method for determination of [Chl *a*] was therefore an important first step in assessing the impact of treatment on the phytoplankton.

In Chapter 2 ("Comparison of chlorophyll *a* extractions with ethanol and dimethyl sulfoxide/acetone, and a concern about spectrophotometric phaeopigment correction"), [Chl *a*] derived using three solvents (90% ethanol, 95% ethanol or a 3:2 combination of dimethyl sulfoxide and 90% acetone) were compared to determine if any of these solvents was more efficient for extraction of Chl *a* from natural assemblages of cyanobacteria and diatoms than the more widely used 90% acetone. This part of my thesis grew out of an undergraduate Special Project in which I compared total [Chl *a*] to those corrected for the presence of Pha to determine if degraded Chl *a* was present in significant quantities in samples from three central Alberta lakes (and if corrections should therefore be made for its presence). When these spectrophotometrically determined samples appeared to have consistently high proportions of Pha, I decided that for my thesis research, [Chl *a*] corrected for Pha would be more appropriate than total [Chl *a*]; [Pha] would also provide useful information on the relationship between the phytoplankton and the depth of the euphotic zone, the general health of the dominant phytoplankton group, and zooplankton grazing pressure, at the time and depth of sample collection.

The proportion of Pha in total [Chl *a*] in samples collected from the various lakes in 1986 and 1988 seemed unusually high, so additional comparisons were made between [Chl *a*] and [Pha] derived by HPLC and those derived by spectrophotometry. From these comparisons, I could determine the amount of confidence (if any) I should have in [Pha] that I had measured during the two years of my study. Traditionally, measurement of [Chl *a*] in the Limnology Laboratory (Department of Zoology, University of Alberta) involved spectrophotometric analysis of samples extracted with

95% ethanol, with no correction for Pha. Subsequent to completion of all [Chl *a*] analyses for my thesis, Neveux et al. (1990) concluded that reliable [Pha] could only be determined with HPLC analysis. At the time I was analyzing samples from Amisk Lake for my thesis, HPLC analysis of [Chl *a*] and [Pha] was not available to me.

Based on the results described in Chapter 2, I assumed that while [Pha] determined in this study may represent trends in [Pha] in Amisk Lake, the accuracy of [Pha] is questionable. While recognizing this problem, I wanted to examine the relationship between the proportion of Pha in total [Chl *a*] (%Pha) and the following parameters: temperature, vertical stability of the water column, and phytoplankton species composition. In Chapter 3 ("Spectrophotometrically determined phaeopigment patterns in Amisk Lake"), these relationships are explored.

In Chapter 4 ("Influence of extended water column mixing in spring on the phytoplankton community in "naturally" eutrophic Amisk Lake, Alberta"), the impact of hypolimnetic oxygenation on the phytoplankton community is examined. The extent of vertical, spatial and temporal heterogeneity of [Chl *a*] during the transition year (1988) was compared to that in 1989 (the first full year of treatment) to determine if the effects of hypolimnetic oxygenation were restricted to the treatment basin or if phytoplankton throughout the lake were affected. Water temperature and vertical stability, photosynthetically active radiation (PAR), and nutrient concentrations (total phosphorus, inorganic and organic nitrogen, and soluble reactive silica) were monitored to indicate which factor(s) was correlated with phytoplankton biovolume and species succession, and if this relationship was altered by hypolimnetic oxygenation. These data were collected to test if hypolimnetic oxygenation resulted in a decrease in mean [Chl *a*] during the open-water season, if [Chl *a*] was lower in the treatment basin compared to the untreated basin, if Chl *a* was distributed deeper in the water column compared to historical distributions, and if the dominant phytoplankton species shifted from cyanobacteria to green algae.

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2. Comparison of chlorophyll *a* extractions with ethanol and dimethyl sulfoxide/acetone, and a concern about spectrophotometric phaeopigment correction[1]

2.1 Introduction

The accuracy of chlorophyll *a* (Chl *a*) measurements (and subsequent estimates of phytoplankton biomass) depends on the extraction efficiency of the solvent used and the species of phytoplankton present, as well as the specificity of the technique used for analysis. Numerous organic solvents have been used to extract Chl *a* from phytoplankton; however acetone is the most common (Richards and Thompson 1952; Moss 1967; Strickland and Parsons 1972; Daemen 1986), particularly for marine phytoplankton. Unfortunately, the extraction efficiency of acetone is low for most green algae and some cyanobacteria, particularly freshwater species; methanol, ethanol and various combinations of dimethyl sulfoxide and 90% acetone (DMSO/acetone) are superior (Shoaf and Lium 1976; Holm-Hansen and Riemann 1978; Stauffer et al. 1979; Burnison 1980; Sartory and Grobbelaar 1984). Methanol and ethanol have similar extraction efficiencies from cultures of *Scenedesmus quadricauda*, *Microcystis aeruginosa*, *Chlorella vulgaris* (in exponential phase), *Selenastrum capricornutum*, and *Pediastrum duplex*, as well as from natural samples dominated by *Microcystis aeruginosa* and by diatoms (Sartory and Grobbelaar 1984; Jespersen and Christoffersen 1987).

Various techniques for analysis of Chl *a* concentration ([Chl *a*]) have been compared, including spectrophotometry, fluorometry, spectrofluorometry, and high performance liquid chromatography (HPLC). Recent studies have reported that traditional nonseparative spectrophotometric and fluorometric techniques yield higher [Chl *a*] than HPLC due to their erroneous measurement (and inclusion) of pigments

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and degradation products other than Chl *a* (Mantoura and Llewellyn 1983; Sartory 1985; Daemen 1986; Murray et al. 1986; Neveux et al. 1990). Neveux et al. (1990) also found major discrepancies in phaeopigment concentrations ([Pha]) among different techniques, with spectrophotometry and fluorometry producing the highest [Pha], HPLC producing the lowest and spectrofluorometry producing intermediate [Pha].

The primary goal of this study was to compare [Chl *a*] extracted from natural assemblages of freshwater cyanobacteria and diatoms with ethanol (either 95% or 90%) and a 2:3 mixture of DMSO and 90% acetone (DMSO/acetone). Comparisons of the extraction efficiencies of ethanol and DMSO/acetone from cyanobacteria and/or diatoms have not been published, but heated 90% ethanol and heated DMSO/acetone extract similar amounts of total Chl *a* (Chl *a* + Pha) from cultures of a green alga, *Selenastrum capricornutum* (Sartory and Grobbelaar 1984). A secondary goal was to observe the relative accuracy of [Chl *a*] and [Pha] derived from spectrophotometric and HPLC analyses for natural assemblages of freshwater cyanobacteria and diatoms. These values were then compared with [Chl *a*] and [Pha] determined with these techniques from phytoplankton cultures and natural assemblages of marine and estuarine phytoplankton (Mantoura and Llewellyn 1983; Sartory 1985; Daemen 1986; Murray et al. 1986; Neveux et al. 1990).

2.2 Methods and Materials

Two mesotrophic lakes (Narrow and Long) and one naturally eutrophic lake (Island) in north-central Alberta, dominated by cyanobacteria (*Aphanizomenon flos-aquae* and *Anabaena* spp.) and diatoms (*Asterionella formosa* and *Cyclotella* spp.), were sampled four to eight times during the summer of 1986. Water collected with an aluminum drop-sleeve water bottle from two to 10 depths in the euphotic zone was stored in 2-L brown polyethylene bottles in coolers with ice packs until they could be returned to the laboratory and refrigerated at 4°C.

Four 300-mL (Island Lake) or four 700-mL (Narrow and Long lakes) subsamples were filtered within 8 h of collection onto Whatman GF/C filters at -50

kPa. (Subsamples from the eutrophic and mesotrophic lakes were of different volumes to prevent clogging of the filter pores during filtration.) The two filters for 95% ethanol extraction were folded and placed in plastic petri dishes with tight-fitting lids. The two filters for DMSO/acetone extraction were folded and placed in 20-mL glass vials with teflon-lined screw caps. The vials and petri dishes were wrapped in foil and stored at -20°C for up to 3 wk before spectrophotometric analysis and for several months before HPLC analysis. All work was performed under low, incandescent light conditions.

Similar sample collections were made on one date in July 1989, except that a greater volume of water was collected from each site at each depth, and pooled. From each pooled sample, four filters were prepared for 95% ethanol extraction, five for DMSO/acetone extraction, and six for 90% ethanol extraction. Four filters from each solvent were analyzed spectrophotometrically and the remainder were analyzed by HPLC. Subsamples were the same volumes as in 1986 for each lake. All filters were stored in plastic petri dishes with tight-fitting lids, except those which were to be extracted with DMSO/acetone and analyzed by spectrophotometry, which were stored in the same type of glass vials used in 1986.

Two spectrophotometric methods were evaluated in 1986 (extraction with 95% ethanol and DMSO/acetone). Extraction with 95% ethanol was based on M. Ostrofsky's (Biology Department, Allegheny College, Meadville, PA, unpubl.) method described in Bergmann and Peters (1980), which measures total [Chl *a*] only. $MgCO_3$ was added as the last 25 mL of subsample were filtered to prevent degradation of Chl *a* in the extract (Vollenweider 1974). DMSO/acetone extraction was based on Burnison (1980), which includes correction for [Pha] by acidification of the sample, and which does not include the addition of $MgCO_3$. The filter/solvent slurries (from both solvents) were stored overnight in the refrigerator. Absorbance was read with a Bausch and Lomb Spectronic 100 spectrophotometer (8-mL cell, 10-cm path length, 8-nm slit width) at 750, 665 and 649 nm against a 95% ethanol blank and at 750 and 664 nm against a DMSO/acetone blank. The spectrophotometer's wavelength settings

were calibrated with a pure Chl *a* standard (Sigma Chemicals, St. Louis, MO). The instrument was zeroed at each wavelength against the appropriate solvent blank.

In 1989 a third spectrophotometric method was added to the evaluation: extraction with 90% ethanol was based on Nusch (1980), which includes correction for [Pha] by acidification of the sample. $MgCO_3$ was not added to the samples. The filter/solvent slurries (from all three solvents) were stored overnight in the refrigerator before absorbance was read with a Milton Roy Spectronic 1001 spectrophotometer (8-mL cell, 10-cm path length, 2-nm slitwidth) at 750 and 665 nm against a 90% ethanol blank. This instrument was calibrated to the Spectronic 100 used in 1986, and the appropriate correction factor was applied to the 1989 concentrations.

In 1989, samples for HPLC analysis were prepared as for spectrophotometric determination (see above). One frozen filter from each sample was extracted with DMSO/acetone according to Burnison (1980) and two filters from each sample were extracted with 90% ethanol according to Sartory and Grobbelaar (1984). All samples were allowed to cool at room temperature in the dark for 1 h. One millilitre of the extract was centrifuged at 4000*g* in a Fisher centrifuge (model 59) for 1 min to quickly remove the glass fibers. The supernatant was filtered through a 4-mm PTFE filter (0.2-µm pore-size) before 100 µL was injected onto the column. Clarified samples were stored in the dark at room temperature for no longer than 30 min before injection. The HPLC analysis was performed with a Waters HPLC system with the 600E multisolvent delivery system and an LC-18 reverse phase column (Supelco, 5-µm particle size). The isocratic mobile phase was methanol, water and acetone (42:5:53). A Varian 2070 spectrofluorometer (excitation 420 nm, emission 665 nm) was used for pigment quantification (Chl *a* = Chl *a* peak plus allomerized Chl *a* peaks). Purified Chl *a* and Chl *b* were obtained from Sigma Chemicals (catalog Nos. C-6144 and C-5878), and Pha were prepared by acidification (Burnison, unpubl.). Ninety-percent acetone solutions of each chlorophyll and phaeophytin were prepared and quantified spectrophotometrically with the specific absorption coefficients of Jeffrey and Humphrey (1975).

Total [Chl *a*] (no correction for Pha) derived by spectrophotometry from 95% ethanol, 90% ethanol and DMSO/acetone are referred to as TS_{95}, TS_{90}, and TS_{DA}, respectively. [Chl *a*] (corrected for phaeopigments) from 90% ethanol and DMSO/acetone and measured by spectrophotometry are referred to as CS_{90} and CS_{DA}, respectively, while corresponding [Pha] are referred to as PS_{90} and PS_{DA}, respectively. [Chl *a*] from HPLC analysis of 90% ethanol and DMSO/acetone extracts are referred to as CH_{90} and CH_{DA}, respectively, while corresponding [Pha] are referred to as PH_{90} and PH_{DA}, respectively. [Chl *a*] and [Pha] measured by HPLC were combined to provide 'total' [Chl *a*] for comparison to estimates of total [Chl *a*] determined by spectrophotometry, and are referred to as TH_{90} and TH_{DA} (from 90% ethanol and DMSO/acetone extracts, respectively).

Statistical analyses were performed on the mean concentrations (when there was more than one subsample analyzed) from the various solvents and techniques for each sample with Statistical Analysis System (SAS). Analyses of variance (ANOVA) were performed to determine differences in [Chl *a*] among solvents (95% ethanol, 90% ethanol and DMSO/acetone) and/or between techniques (spectrophotometry and HPLC). Student-Newman-Keuls (SNK) test was used for multiple comparisons of total [Chl *a*] among the three solvents.

2.3 Results

[Chl *a*], [Pha] and total [Chl *a*] from the two techniques and three solvents are summarized in Table 2.1. A composite HPLC chromatogram of chlorophylls *a* and *b* and phaeophytins *a* and *b* is shown in Fig. 2.1, and the HPLC chromatogram of the DMSO/acetone and 90% ethanol extracts of one of the samples is presented in Fig. 2.2.

All total [Chl *a*] (TS_{95}, TS_{90}, TS_{DA}, TH_{90}, and TH_{DA}) from both years were compared by two-factor ANOVA (technique x solvent). The three solvents did not yield significantly different total [Chl *a*] ($F = 0.35$; df = 2, 190; $P > 0.5$), nor was there significant interaction between techniques and solvents ($F = 0.38$; df = 1, 190; P

> 0.5). Multiple comparisons also revealed no significant difference among total [Chl *a*] from the three solvents (SNK; df = 190; $P > 0.05$). The three solvents (95% ethanol, 90% ethanol and DMSO/acetone) are thus comparable for Chl *a* extraction from natural assemblages of freshwater cyanobacteria and diatoms. The two techniques yielded significantly different total [Chl *a*] ($F = 6.71$; df = 1, 190; $P < 0.05$). Since HPLC analysis was not done in 1986, only 1989 data were used for further comparisons of techniques.

TS_{90}, TS_{DA}, TH_{90}, and TH_{DA} concentrations from 1989 were compared by blocked two-factor ANOVA to determine if the techniques yielded different concentrations. (TS_{95} data were not included since 95% ethanol extracts were only analyzed by spectrophotometry.) Mean total [Chl *a*] from spectrophotometry and HPLC (from both solvents combined) were 4.2 and 2.6 $\mu g \cdot L^{-1}$, respectively, and were significantly different ($F = 8.25$; df = 1, 30; $P < 0.05$). As with the comparison of the complete data set, there was no significant difference in total [Chl *a*] between solvents with this data set ($F = 1.35$; df = 1, 30; $P > 0.25$), nor were there significant interactions between techniques and solvents ($F = 0.72$; df = 1, 30; $P > 0.25$). Thus choice of technique had a significant impact on estimates of total [Chl *a*], with HPLC analysis producing lower total [Chl *a*] than spectrophotometric analysis.

PS_{90}, PS_{DA}, PH_{90}, and PH_{DA} concentrations from 1989 were compared by blocked two-factor ANOVA (technique x solvent), as were CS_{90}, CS_{DA}, CH_{90}, and CH_{DA} concentrations from 1989, to determine if solvent or technique affected [Pha] or [Chl *a*]. The two techniques yielded significantly different [Pha] ($F = 12.92$; df = 1, 30; $P < 0.005$), but there was no significant difference in [Pha] between solvents ($F = 1.67$; df = 1, 30; $P > 0.1$), nor was interaction between techniques and solvents significant ($F = 1.73$; df = 1, 30; $P > 0.1$). [Pha] measured by spectrophotometry ranged from 18 to 64% (mean = 30%) of total [Chl *a*] (mean [Pha] = 1.7 $\mu g \cdot L^{-1}$). Pha contributed only 0 to 7% (mean = 0.8%) of total [Chl *a*] measured by HPLC (mean [Pha] = 0.025 $\mu g \cdot L^{-1}$). There was no significant difference in [Chl *a*] between techniques ($F = 0.19$; df = 1, 30; $P > 0.5$) or between solvents ($F = 0.04$; df = 1, 30;

$P > 0.75$), nor was interaction between techniques and solvents significant ($F = 0.48$; df = 1, 30; $P > 0.25$). Results of this part of the study confirm that 90% ethanol and DMSO/acetone are equally suitable for extracting Chl *a* from natural assemblages of freshwater cyanobacteria and diatoms. However, spectrophotometry may over-estimate [Pha] and total [Chl *a*] concentrations.

2.4 Discussion

Historically, acetone has been the solvent of choice for Chl *a* extraction (especially in marine systems), but use of ethanol and DMSO is becoming more common for freshwater phytoplankton, where green algae and cyanobacteria (from which extraction with acetone is poor) form a large proportion of the biomass. The 95% ethanol method used in the present study has been used in the Limnology Laboratory at the University of Alberta for over 10 yr for Chl *a* analysis (Prepas and Trew 1983; Trimbee and Prepas 1987; Prepas and Murphy 1988; Prepas et al. 1990), as well as by others (Kalff 1983; Smith et al. 1984; Kalff and Watson 1986; Morin and Peters 1988). Ninety-percent ethanol has also been used for Chl *a* extraction (Nusch 1980; Sartory and Grobbelaar 1984; Sartory 1985; Jespersen and Christoffersen 1987; Jacobsen and Rai 1990). Various studies have also been published in which DMSO (with and without acetone) was used for Chl *a* extraction (Seely et al. 1972; Shoaf and Lium 1976; Hiscox and Israelstam 1979; Burnison 1980; Speziale et al. 1984).

I recognize that there are several differences (besides solvents) between the spectrophotometric methods compared in this study. However, I wanted to make as few alterations as possible to the published methods. First, $MgCO_3$ was added to samples extracted with 95% ethanol, but it was not added to those extracted with DMSO/acetone or 90% ethanol. The purpose of $MgCO_3$ was to prevent degradation of Chl *a* during storage and extraction (Vollenweider 1974). Although filters analyzed by HPLC were stored for considerably longer periods of time before analysis (several months) than were filters analyzed by spectrophotometry (up to 3 wk), HPLC [Pha]

were much lower than those derived by spectrophotometry (0.025 and 1.7 $\mu g \cdot L^{-1}$, respectively). These results are consistent with Sartory and Grobbelaar's (1984) conclusion that the addition of $MgCO_3$ has no effect on Chl *a* degradation. Furthermore, numerous studies have reported that $MgCO_3$ adsorbs Pha thus resulting in under-estimates of [Pha] (Holm-Hansen and Riemann 1978). Adsorption of Pha by $MgCO_3$ may explain why mean TS_{95} concentrations (6.3 and 3.2 $\mu g \cdot L^{-1}$ in 1986 and 1989, respectively) were slightly lower than mean TS_{DA} concentrations (7.0 and 3.6 $\mu g \cdot L^{-1}$ in 1986 and 1989, respectively) and mean TS_{90} concentration in 1989 (4.7 $\mu g \cdot L^{-1}$). Second, filters prepared for DMSO/acetone extraction then spectrophotometric analysis were placed in glass vials with teflon-lined lids and then frozen, while all other filters were placed in plastic petri plates with tight-fitting lids and frozen. However, the similarity among total [Chl *a*], based on the three solvents, indicates that the use of different storage containers did not affect total [Chl *a*].

The lack of significant difference between total [Chl *a*] from the various solvents within each technique indicates that the extraction efficiencies of 95% ethanol, 90% ethanol and DMSO/acetone are comparable for these natural assemblages of predominantly cyanobacteria and diatoms. This information complements Sartory and Grobbelaar's (1984) findings that heated ethanol and heated DMSO/acetone are equally efficient for extracting total Chl *a* from *Selenastrum capricornutum*.

Besides extraction efficiency, toxicity and cost may also be considered when selecting solvents for Chl *a* analysis. DMSO absorbs rapidly into the skin (Rammler and Zaffaroni 1967), resulting in irritation, redness, itching and scaling (Windholz 1976). However, its cutaneous toxicity is relatively low (LD_{50} in rats = 40 $g \cdot Kg^{-1}$; Mason 1971). Ethanol, DMSO and acetone all have relatively low oral toxicities (LD_{50} in rats = 13.7 $g \cdot Kg^{-1}$, > 20 $g \cdot Kg^{-1}$, and 10.7 $mL \cdot Kg^{-1}$, respectively; Windholz 1976). The cost of ethanol is about one-fourth that of DMSO/acetone, which becomes important in studies involving analysis of a large number of samples.

Total [Chl *a*] determined by HPLC from both ethanol and DMSO/acetone were lower than those derived by spectrophotometry (Table 2.1). Previous studies have

attributed this difference to the presence of accessory chlorophylls (*b* and *c*), other green or blue-green pigments, carotenoid pigments, and/or degradation products, which have absorbances similar to Chl *a*, but which are chromatographically distinguishable from Chl *a* (Gieskes and Kraay 1983; Mantoura and Llewellyn 1983; Hallegraeff and Jeffrey 1985; Sartory 1985; Daemen 1986; Schanz and Rai 1988; Jacobsen and Rai 1990; Neveux et al. 1990). These compounds interfere with spectrophotometric analysis, resulting in over-estimations of total [Chl *a*]. I made corrections for phaeopigments, but other compounds may have been present in my samples that were not distinguished by spectrophotometry and that were thus included in spectrophotometric [Chl *a*] measurements. The chromatogram of the calibration pigments is shown in Fig. 2.1. The pigments were well separated within the 10-min isocratic run. Chl *b* does not give an equal fluorescent response under the excitation and emission wavelengths chosen. A typical chromatogram of a phytoplankton sample is presented in Fig. 2.2. The fluorescent detector is very selective and only the chlorophyllous pigments respond. In this particular sample, DMSO/acetone extracted more pigment from the algae than did 90% ethanol. The slight discrepancy between the Chl *a* peak between the two solvents lies within the ±0.2-min window. DMSO/acetone also gave a higher amount of allomerized Chl *a*, but this was added onto the Chl *a* peak (Murray et al. 1986). Fluorescent peaks (retention time about 1.3 min) were noted in both the DMSO/acetone and 90% ethanol extracts, and comprised 13.5% and 21.2% of the Chl *a* response, respectively. However, until a thorough analysis of this material is done, it is not known whether it is solely responsible for the difference between HPLC and spectrophotometric analysis of phytoplankton. Certainly, chlorophyllides will be present in this fraction (Murray et al. 1986).

The proportion of phaeopigments was considerably higher in both 90% ethanol and DMSO/acetone extracts analyzed by spectrophotometry than in extracts analyzed by HPLC (mean = 30% and 0.8%, respectively; Table 2.1). Murray et al. (1986) and Neveux et al. (1990) also found discrepancies in phaeopigments between techniques and concluded that spectrophotometric measurement of phaeopigments is often

unreliable. If spectrophotometry over-estimates [Pha], corresponding [Chl *a*] (corrected for [Pha]) may be similarly under-estimated. However, in this study there was no significant differences in [Chl *a*] between techniques, even though [Pha] were significantly different between techniques. This is likely due to the large proportion of Chl *a* in total [Chl *a*] (mean = 99.2% and 70% for HPLC and spectrophotometry, respectively) compared to the smaller proportion of Pha in total [Chl *a*] (mean = 0.8% and 30% for HPLC and spectrophotometry, respectively).

I conclude that ethanol is an appropriate solvent for extracting Chl *a* from natural assemblages of freshwater cyanobacteria and/or diatoms found in these lakes. Its extraction efficiency and health hazards are similar to DMSO/acetone, but it lacks DMSO's strong, unpleasant odour and it is less expensive. Considering these advantages, I am surprised that it is not used more widely by limnologists for Chl *a* extraction.

Results from this study indicate that spectrophotometry is a suitable technique for determining [Chl *a*] (corrected for Pha). Samples can be processed rapidly and with relatively little technical skill. Spectrophotometric determination of [Pha] is not recommended because of its unreliable nature. For studies requiring measurements of [Pha] or accessory pigments, HPLC analysis is recommended.

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Table 2.1: Mean concentrations (±*SE*) of phaeopigment-corrected chlorophyll *a* (Chl *a*), phaeopigments (Pha) and total Chl *a* (i.e., Chl *a* + Pha) ($\mu g \cdot L^{-1}$) from three solvents and two techniques in water samples collected from three mesotrophic to eutrophic Alberta lakes. Spec = concentrations derived by spectrophotometry, HPLC = concentrations derived by high performance liquid chromatography, n = 70 in 1986 and n = 11 in 1989. Blanks indicate no data.

Year Technique	Solvent	Chl *a*		Pha		Total	
1986							
Spec	95% ethanol					6.3	±0.67
	DMSO/acetone	3.8	±0.43	3.2	±0.57	7.0	±0.90
1989							
Spec	95% ethanol					3.2	±0.81
	90% ethanol	2.4	±0.65	2.3	±0.98	4.7	±1.56
	DMSO/acetone	2.5	±0.64	1.1	±0.31	3.6	±0.90
HPLC	90% ethanol	2.6	±0.69	0.02	±0.008	2.6	±0.69
	DMSO/acetone	2.5	±0.76	0.03	±0.018	2.5	±0.77

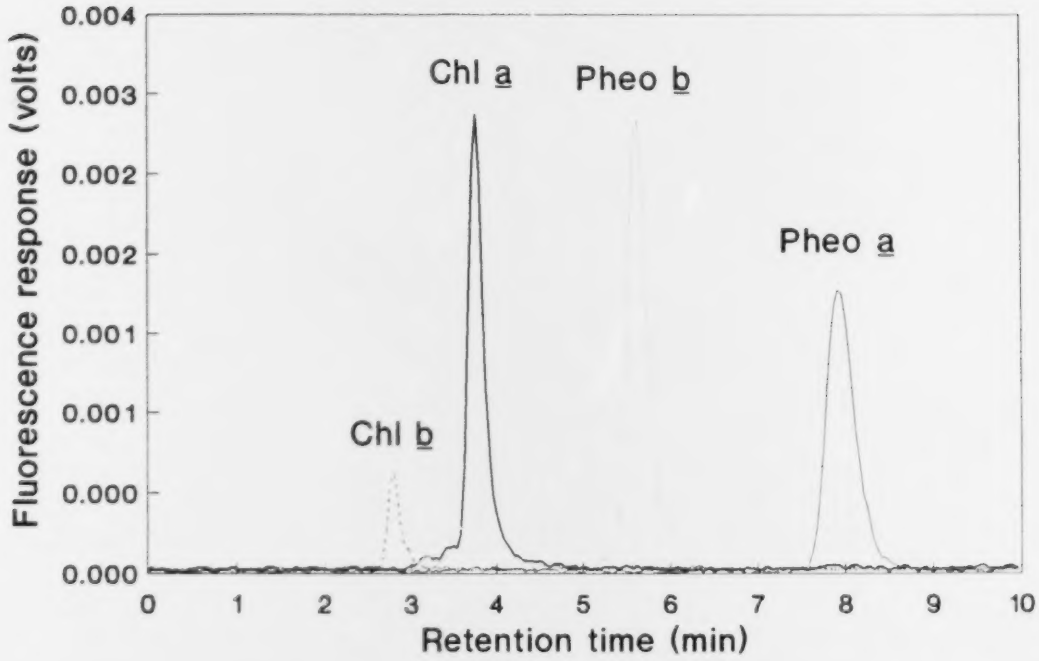

Fig. 2.1: Composite HPLC chromatogram of chlorophyll *a* and *b* and phaeophytin *a* and *b*.

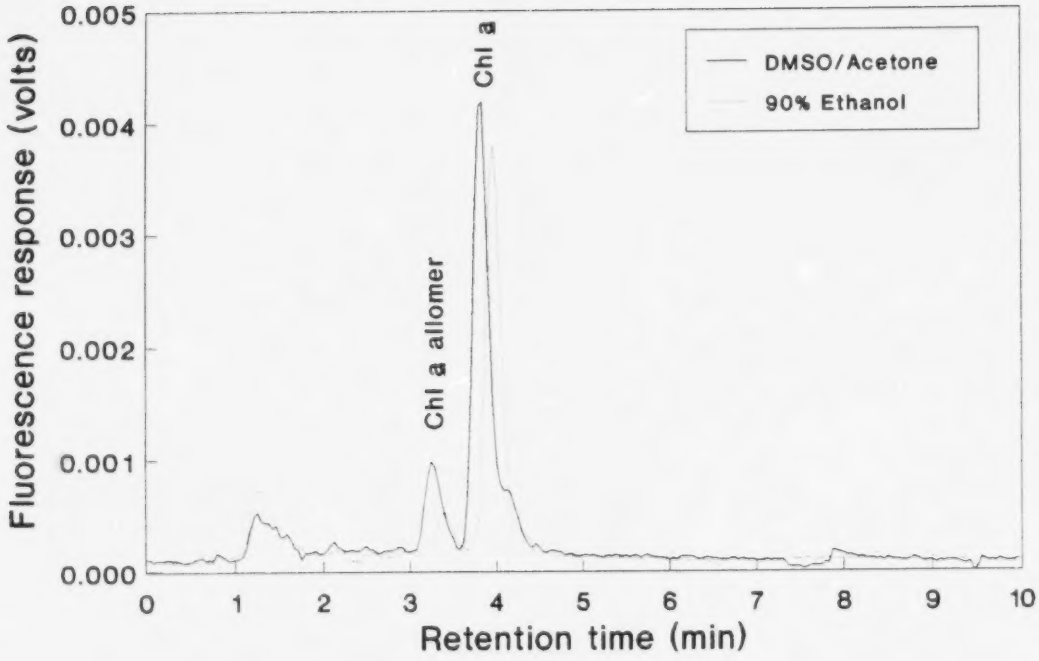

Fig. 2.2: HPLC chromatogram of DMSO/acetone extract (solid line) and 90% ethanol extract (dotted line) of samples taken from Island Lake at a depth of 5.5 m.

3. Spectrophotometrically Determined Phaeopigment Patterns in Amisk Lake

3.1 Introduction

Distinction between active chlorophyll *a* (Chl *a*) and degraded Chl *a* (i.e., phaeopigments) may provide useful information about the depth of the euphotic zone, zooplankton grazing pressure, or the general health of the phytoplankton community. Variation in the proportion of phaeopigments (Pha) in total [Chl *a*] reflects variation in the physical, chemical and biological parameters influencing the phytoplankton at the time and location of sample collection. Initially, I decided that distinction between active [Chl *a*] and [Pha] would be more appropriate than total [Chl *a*] for determining temporal and spatial patterns of [Chl *a*], and for assessing the impact of hypolimnetic oxygenation on the phytoplankton community in Amisk Lake. I also felt that determination of [Pha] would provide information about zooplankton grazing pressure, which might be influenced by hypolimnetic oxygenation. The method traditionally used in the Limnology Laboratory (Department of Zoology, University of Alberta) measures only total [Chl *a*], with no correction made for [Pha] (Ostrofsky, as described in Bergmann and Peters 1980), and uses 95% ethanol as the solvent. To take advantage of the many benefits of ethanol compared to other more widely used solvents (Webb et al. 1992), I selected Nusch's (1980) 90% ethanol extraction method for spectrophotometric determination of [Chl *a*] and [Pha].

Subsequent to completion of all [Chl *a*] and [Pha] analyses for this study, Neveux et al. (1990) concluded that spectrophotometric correction for the presence of Pha is not precise, and accurate [Pha] can only be obtained with high performance liquid chromatography (HPLC) analysis. Results from several Alberta lakes also support this conclusion (Webb et al. 1992). Therefore, I have assumed that while [Pha] determined in this study may represent trends in [Pha] in Amisk Lake, the accuracy of [Pha] is questionable. While recognizing this problem, I wanted to examine the relationship between the proportion of Pha in total [Chl *a*] and the following parameters: temperature, vertical stability of the water column, and phytoplankton

species composition in Amisk Lake. I anticipated that %Pha would increase with depth. However, the influence (if any) of temperature, turbulence, or phytoplankton species composition on %Pha was uncertain.

3.2 Methods and Materials

In 1988 and 1989, a total of 1696 water samples were collected from Amisk Lake, Alberta (Fig. 3.1). Water was collected at depths of 3, 5.5, 8, 10.5, 13, and 18 m (representing the mid-epilimnion, lower epilimnion, metalimnion, upper hypolimnion (10.5 and 13 m), and mid-hypolimnion, respectively). "Epilimnion" refers to the upper, mixed portion of the water column, "metalimnion" refers to the zone below the epilimnion in which there is > 1°C change in temperature for every 1 m change in depth, and "hypolimnion" refers to the portion of the water column between the metalimnion and the bottom sediments (Wetzel 1983). For the purpose of simplicity in this thesis, these terms refer to the corresponding strata during periods of mixing as well as during thermal stratification.

The sampling program was more intensive in 1989 than in 1988. In 1988, two replicate samples for [Chl *a*] determination were collected biweekly from late May to August, and monthly in September and October, from each of three depths (3, 8, and 18 m) at each of six sites on each sampling date (Fig. 3.1). In 1989, two replicate samples for [Chl *a*] analysis were collected weekly from early May until August, and biweekly in September and October, from each of six depths (3, 5.5, 8, 10.5, 13, and 18 m) at the same six sites on each sampling date. In both years, biweekly subsamples (monthly in September and October 1988) from each depth at sites N2 and S1 were preserved for phytoplankton identification and enumeration (Lund et al. 1958). On each sampling date in both years, temperature was measured at 1-m intervals from the lake surface to the bottom sediments at sites N2 and S1 in 1988, and at all six sites in 1989, with a Montedoro-Whitney resistance thermometer (model TC-5C).

Water was collected with a 1.5-L aluminum drop-sleeve water bottle and poured into 1-L opaque brown polyethylene bottles. These were stored in coolers with ice packs until return to the laboratory. Samples were refrigerated overnight (4°C) in

1988, whereas in 1989, samples were filtered immediately upon return to the laboratory. Two 300-mL subsamples from each bottle (i.e., from each replicate sample) were filtered through Whatman GF/C filters at -50 kPa. The filters were folded and placed in plastic petri dishes with tight-fitting lids. The petri dishes were wrapped in aluminum foil and frozen for up to 3 wk before extraction.

Extraction of Chl *a* was based of Nusch's (1980) method. Each filter was torn into several pieces and placed in 15-mL polystyrene vials. Ten millilitres of hot (72°C) 90% ethanol was poured over each filter. The vials were then sealed with laboratory film and shaken until the disintegrated filters became a slurry. The vials were wrapped in foil and refrigerated overnight. Samples were filtered again through GF/C filters with an additional 5 mL of 90% ethanol (at room temperature). The extracts were collected in polystyrene vials.

Absorbances of the extracts were determined with a Milton Roy Spectronic 1001 spectrophotometer (8-mL cell, 10-cm path length, 2-nm slit width). The spectrophotometer was programmed to read absorbance at 750 and 665 nm (Nusch 1980). After absorbances were determined, each sample was returned to its vial; 10 mL of the sample was then acidified with 30 µL of 2N HCl (Nusch 1980). The vials were inverted several times, and within 4 to 30 min, absorbance was read at the same two wavelengths. All work was performed under low incandescent light.

Phytoplankton cells were usually identified to genus (but sometimes to species). At least 10 representative cells from each taxon were measured on at least three dates in each year so that cell volumes could be calculated, based on the closest geometric shape.

Mean concentration of the two subsamples was calculated for each replicate; the two replicates from each depth at each site were then considered independent samples and used for statistical analyses. Statistical analyses were done with Statistical Analysis System (SAS) on a personal computer. Analyses of variance (ANOVA's) were performed to assess if the mean %Pha was different between years and among depths. Student-Newman-Keuls (SNK) tests were performed to determine which portions of the water column had similar proportions of Pha. My thesis focuses on

phytoplankton and [Chl *a*], so emphasis is on the upper 20 m of the water column, since this is the stratum of the lake in which phytoplankton and thus Chl *a* are most likely to be concentrated in meaningful quantities, and likely to be incorporated into the food chain.

3.3 Results

The ice left Amisk Lake on April 23 1988, and according to water temperature profiles, thermal stratification was established prior to 16 May (E. E. Prepas, unpubl.), so there was little or no spring mixed period in 1988 (Fig. 3.2). In 1989, the lake was ice-free by 3 May, but thermal stratification was not established until early June (Fig. 3.3). Based on vertical temperature profiles, the open-water season was divided into three distinct periods: 1) the spring mixed and 2) fall mixed periods, during which there was no metalimnion (i.e., no zone of > 1°C change in temperature for every 1 m change in depth; Wetzel 1983), and 3) the thermally stratified period, during which the metalimnion was well-defined. Thus the 1988 thermally stratified period included sampling dates from 24 May to 20 September, and the fall mixed period was represented by 18 October. In 1989, the spring mixed period included sampling dates from 8 to 30 May, the thermally stratified period from 6 June to 18 September, and the fall mixed period from 2 to 16 October.

Mean %Pha was significantly different between 1988 and 1989 (two-factor ANOVA (year x depth); $F = 315$; df = 1, 1689; $P < 0.0001$; Table 3.1). Mean %Pha at all sampling depths was 49% and 33% in 1988 and 1989, respectively (Table 3.1). Mean %Pha was significantly different among all three depths in 1988 (SNK; df = 321; $P < 0.05$; Table 3.1), while multiple comparisons of mean %Pha among depths in 1989 indicated five significantly different groups (SNK; df = 1366; $P < 0.05$; Table 3.1).

Percent Pha followed one of four patterns with depth on each date during 1988 and 1989: 1) %Pha similar at all sampling depths (i.e., %Pha differed by < 10% among all depths); 2) increasing %Pha with depth between 3 and 18 m, but not

necessarily at a constant rate; 3) increasing %Pha with depth, but with a peak at some intermediate depth; and 4) decreasing %Pha from 3 to 8 m, then an increase from 8 to 18 m (Fig. 3.2 and 3.3). The first pattern occurred on the first and last sampling dates of both 1988 and 1989. The second pattern occurred on all but the first and last sampling dates during the 1988 thermally stratified period; in 1989, this pattern occurred on two dates during the spring mixed period, and on four dates in the mid- to late thermally stratified period. The third pattern was not recorded in 1988, but was the most frequent pattern in 1989, occurring on 11 dates during the late spring mixed period, the thermally stratified period, and the early fall mixed period. The fourth pattern was limited to the last date of the 1988 thermally stratified period. Fewer sampling depths in 1988 compared to 1989 may have been a factor in the frequency of occurrence of the various patterns.

In 1988, the highest [Chl *a*] (corrected for [Pha]) were recorded at a depth of 3 m, and the highest [Pha] occurred at a depth of 8 m (Fig. 3.4). In 1989, the highest corrected [Chl *a*] were recorded at a depth of either 3 or 5.5 m, whereas the highest [Pha] occurred at a depth of 5.5 or 8 m (Fig. 3.4).

Four groups of phytoplankton were identified in 1988 and 1989: diatoms, cyanobacteria, green algae, and cryptophytes. Of these, cyanobacteria and diatoms were the most important groups in terms of cell biovolume. Since phytoplankton cells in the hypolimnion were likely viable only during periods of mixing, efforts to determine phytoplankton species succession (and the possible relationship with %Pha) focused on epilimnetic and metalimnetic populations. In 1989, mean phytoplankton biovolume from depths of 3 and 5.5 m were considered as representative of the epilimnion on each date.

Throughout 1988, cyanobacteria (particularly *Aphanizomenon flos-aquae* and *Anabaena flos-aquae*) were the dominant phytoplankton in the epilimnion and metalimnion, contributing from 59 to 99% and from 30 to 97% of the total phytoplankton biovolume, respectively (Fig. 3.5). In 1989, diatoms (particularly *Cyclotella* spp. and *Asterionella formosa*) were the dominant phytoplankton throughout

the water column during the spring mixed period (85 to 92% and 83 to 97% of total biovolume in the epilimnion and metalimnion, respectively); cyanobacteria (same species as in 1988) were dominant during the thermally stratified and fall mixed periods (56 to 98% and 20 to 93% in the epilimnion and metalimnion, respectively; Fig. 3.5).

3.4 Discussion

Spectrophotometrically determined %Pha varied significantly between years in Amisk Lake. Some of this difference in %Pha might be attributable to differences in sample handling: in 1988 samples were refrigerated overnight before being filtered for Chl *a* and Pha analysis, while in 1989, samples were filtered immediately upon return to the laboratory. The increased storage time (i.e., extended period of time in an aphotic environment) may be at least partially responsible for higher mean %Pha in 1988 compared to values for 1989 (Yentsch 1965). The proportion of Pha in total [Chl *a*] with depth followed one of four patterns on each date. Changes from one pattern to another during the season appear to be related to development and enhancement of thermal stratification and/or to a shift in dominance of phytoplankton biovolume from diatoms to cyanobacteria.

The first pattern (%Pha similar at all depths) occurred on the first and last sampling dates in both 1988 and 1989. On three of these dates, the water column was mixed to a depth of at least 18 m, so there was no temperature barrier to prevent upward or downward mixing of cells, and thus %Pha was similar at all sampling depths. However, %Pha also followed this pattern on the first sampling date in 1988, when the water column was thermally stratified. On this date, the phytoplankton population (mostly cyanobacteria) appeared to be within an exponential growth phase, in which case the majority of cells would have been healthy, with little degradation of Chl *a* occurring.

The second pattern (%Pha increasing with depth between 3 and 18 m without any noticeable peaks between these depths) occurred on seven out of nine sampling dates in 1988, indicating a high proportion of healthy, photosynthetically active cells

in the epilimnion and increasing proportions of inactive cells in the metalimnion and mid-hypolimnion. In 1989, this pattern occurred on nine out of 11 sampling dates from the middle of the spring mixed period to the middle of the thermally stratified period (i.e., between 17 May to 25 July). During this period, thermal stratification was established. Between 17 and 30 May, diatoms were prominent throughout the water column. The thermal gradient was weak (i.e., from 3 to 7°C difference between the surface and 20 m, but no metalimnion as previously defined), resulting in the rapid settling (mixing) of intact, Pha-containing diatom cells and thus high %Pha in the deep waters. With the development of thermal stratification (and the decline in turbulence in the water column) in early June 1989, diatoms had no means of maintaining their position within the euphotic zone, and the population began to decline. The greater temperature gradient, especially within the metalimnion, probably slowed the descent of diatom cells through the water column such that many of the cells had deteriorated and released their Pha by the time they reached the lower sampling depths, resulting in low %Pha at 13 and 18 m on 6 June. (Once released to the water, free Pha would not be retained on filters during sample analysis.) If the majority of the diatom population collapsed immediately prior to 16 June, it is possible that even if some frustules had lost Pha while settling through the metalimnion, a sufficient number of cells may have remained intact (as indicated in Fig. 3.5) to give the high %Pha (42%) at 18 m on this date. This pattern of increasing %Pha with depth was also evident on 5 September, at which time thermal stratification was beginning to weaken (i.e., temperature gradient within the metalimnion was less than 6°C). The reduced thermal gradient presented less of a barrier, enabling cells to settle more rapidly such that they were still intact at 18 m and thus still retained Pha.

The third pattern (increasing %Pha with depth but with a peak of %Pha at some intermediate depth) was evident on six out of eight sampling dates in the last part of the 1989 thermally stratified period. During this period, cyanobacteria were the predominant contributors to phytoplankton biovolume, but relatively few cells were found at depths greater than 8 m. By 18 July the temperature gradient between the top and bottom of the metalimnion was greater than 10°C. Active cyanobacteria probably

remained within the epilimnion through their ability to regulate buoyancy, thus taking advantage of suitable light conditions and warm temperatures. Only dying/dead cells would settle out, but the steep temperature gradient in the metalimnion probably slowed the rate of descent, resulting in a large number of inactive cells at 8 m and thus peaks in %Pha at this depth on 18 July and from 9 to 22 August. Because cyanobacteria do not have true cell walls, they are particularly susceptible to rapid microbial decomposition (Gunnison and Alexander 1975). Below the thermocline, most cells had probably deteriorated and released Pha to the open water, resulting in declines in %Pha and few cyanobacteria cells below 8 m on most dates during this period. This pattern is also evident on the final date of the 1989 thermally stratified period, by which time thermal stratification had weakened and the mixed layer extended to below 8 m. Descent of dying/dead cells from the cyanobacteria bloom out of the mixed layer resulted in %Pha peak at 10.5 m. Below this depth, most cells had presumably deteriorated and lost Pha into the water. This pattern was not recorded in 1988, probably because fewer depths were sampled, thus peaks in %Pha at depths between 3 and 18 m were more likely to be overlooked.

The fourth and final pattern (decreasing %Pha between 3 and 8 m, then increasing between 8 and 18 m) was only recorded on the final date of the 1988 thermally stratified period. This was well after the cyanobacteria population had collapsed (Fig. 3.5); old, deteriorating cells combined with decreasing amount of sunlight probably resulted in high %Pha in the epilimnion. Thermal stratification was weakening, so cells settled rapidly through the water column without releasing Pha into the water, resulting in very high %Pha (> 80%) in the mid-hypolimnion on this date.

Some results from this study are in agreement with published studies. As in Pluss See (Rai 1975), the highest [Chl *a*] in Amisk Lake were found in samples collected from the middle of the euphotic zone (i.e., 3 and 5.5 m), and maximum [Pha] were found in samples from the mid- to lower metalimnion, near the bottom of the euphotic zone (i.e., 5.5 and 8 m). Similarities in the pattern of %Pha between these two studies may relate to physical similarities between the study lakes (both have a

temperate location, both exhibit strong thermal stratification during the summer months, and both have a maximum depth of over 25 m). Phytoplankton species composition may also have been similar in the two lakes, but unfortunately, phytoplankton species composition in Pluss See was not given in Rai (1975).

Published Pha proportions to which results of this study were compared were determined by either spectrophotometry or fluorometry. Mean %Pha in Amisk Lake was near or greater than 50% at 8 m (48%) and 18 m (62%) in 1988, while mean %Pha at 3 m in 1988 and at all depths in 1989 was less than 50% (24% to 40%, Table 3.1). In comparison, Pha contributed over 50% of total Chl *a* at all depths sampled in Pluss See (Rai 1975), whereas at a depth of 1 m in Kinnego Bay, %Pha was rarely greater than 10% and was usually closer to 5% of total [Chl *a*] (Jones 1977a). Mean annual %Pha in Amisk Lake at 3 m (the uppermost depth sampled) was 38% and 24% in 1988 and 1989, respectively. Lower %Pha at these depths in Amisk Lake compared to in Pluss See (Rai 1975) may be due to different analytical techniques (spectrophotometry versus fluorometry) and/or different solvents (ethanol versus acetone) used to determine [Chl *a*] and [Pha]. Greater %Pha in Amisk Lake compared to in Kinnego Bay (Jones 1977a) may be due to physical differences between the lakes, the latter being a shallow bay (maximum depth = 3 m) that remained thoroughly mixed throughout the season. Kinnego Bay samples were collected from a depth of 1 m (i.e., within the euphotic zone; Jones 1977b) and Pha (which is light labile; Lorenzen 1967) may have been broken down, resulting in low %Pha. Pha in Kinnego Bay may also have been rapidly mixed to lower depths where no samples were collected.

As previously mentioned, [Pha] determined by spectrophotometry are not necessarily accurate (Neveux et al. 1990; Webb et al. 1992). However, [Pha] determined in this study were likely representative of trends in the proportion of Pha in total [Chl *a*] with depth. As anticipated, %Pha generally increased with depth, although peaks in %Pha frequently occurred at some intermediate depth. Similar %Pha at all sampling depths usually coincided with mixing within the water column, or with cyanobacterial populations in exponential growth phase. Increasing %Pha between 3

and 18 m with no peaks at intermediate depths was associated with a high proportion of healthy, photosynthetically active cells in the epilimnion and increasing proportions of inactive cells in the metalimnion and mid-hypolimnion, particularly during periods of weak thermal stratification. Peak %Pha at metalimnetic depths usually occurred during periods of thermal stratification when the temperature gradient within the metalimnion was large (i.e., > 10°C), when cyanobacteria were the dominant phytoplankton. Finally, minimum %Pha in the metalimnion was associated with a collapsed cyanobacterial population at a time when thermal stratification was weakening. Thus changes from one pattern of %Pha through the water column to another during the open-water season appear to be related to development and enhancement of thermal stratification (which influences whether diatoms or cyanobacteria are the dominant phytoplankton, as well as the rate of settling of dead cells), and to the general health of the phytoplankton.

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Table 3.1: Mean proportions (±*SE*) of spectrophotometrically determined phaeopigments in total chlorophyll *a* concentrations (%Pha) with depth (m) in Amisk Lake during the open-water seasons of 1988 and 1989. n = number of samples; SNK = Student-Newman-Keuls grouping for samples from each year (means with the same letter are not significantly different, $P < 0.05$).

Year	Depth	*n*	%Pha		Range	SNK	
1988	all	324	49.4	±1.02	22 - 80	-	
	3	108	37.5	±1.31	22 - 51	A	
	8	108	48.5	±1.24	44 - 55	B	
	18	108	62.3	±1.83	45 - 80	C	
1989	all	1372	33.1	±0.42	15 - 56	-	
	3	228	23.6	±0.84	15 - 49	A	
	5.5	229	28.1	±0.73	18 - 50	B	
	8	230	33.3	±0.76	20 - 47	C	
	10.5	229	35.5	±0.95	22 - 49	C	D
	13	229	37.9	±1.10	24 - 55	E	D
	18	227	40.1	±1.34	24 - 56	E	

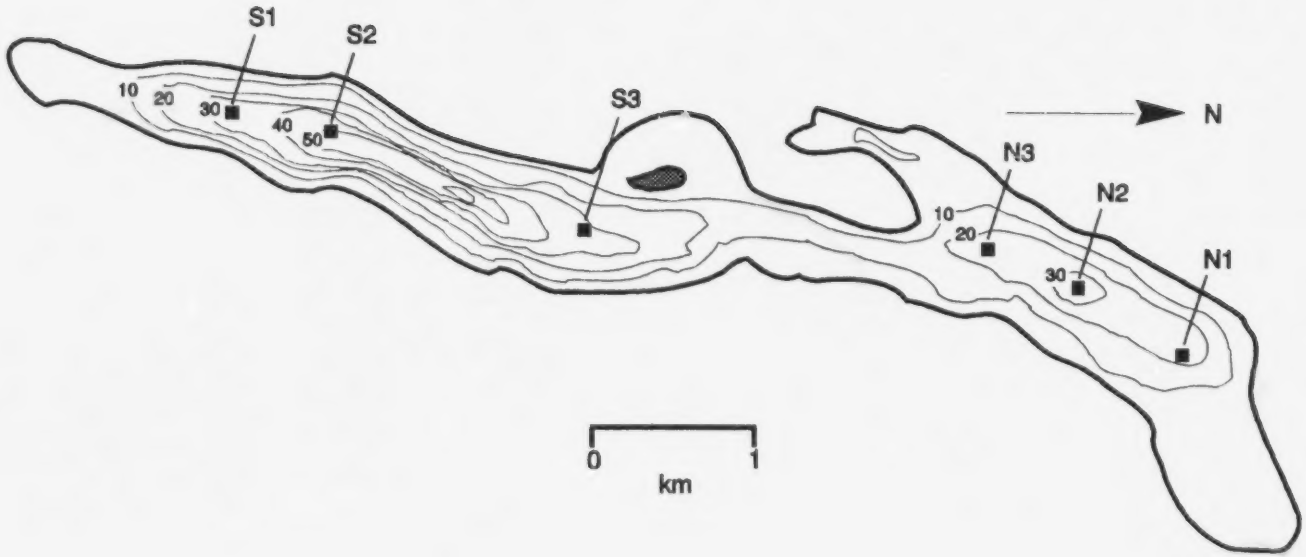

Fig. 3.1: Amisk Lake, Alberta. N1, N2, N3, S1, S2, and S3 = sampling sites.

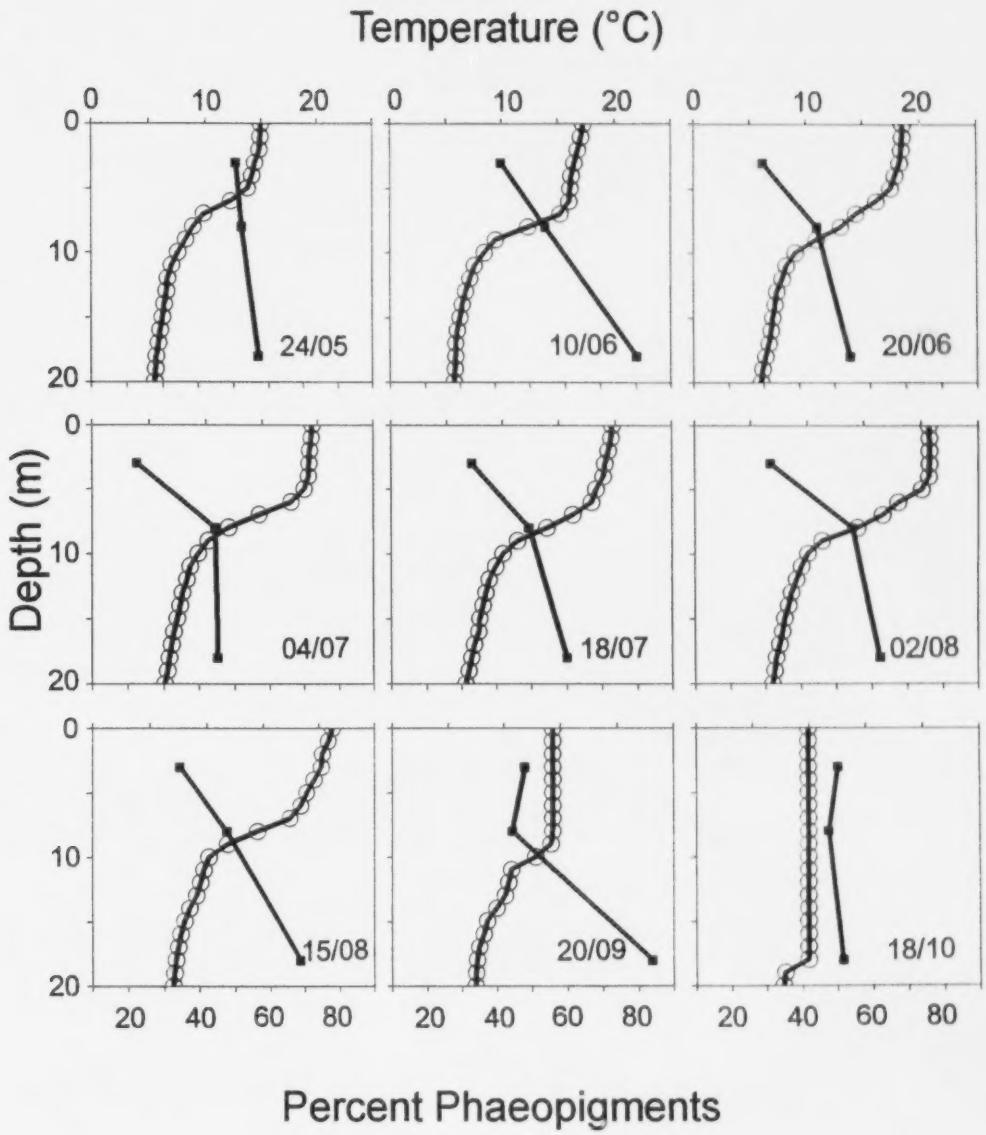

Figure 3.2: Vertical profiles of water temperature (○) and the percentage of phaeopigments in total chlorophyll *a* concentration (■) in Amisk Lake, 1988.

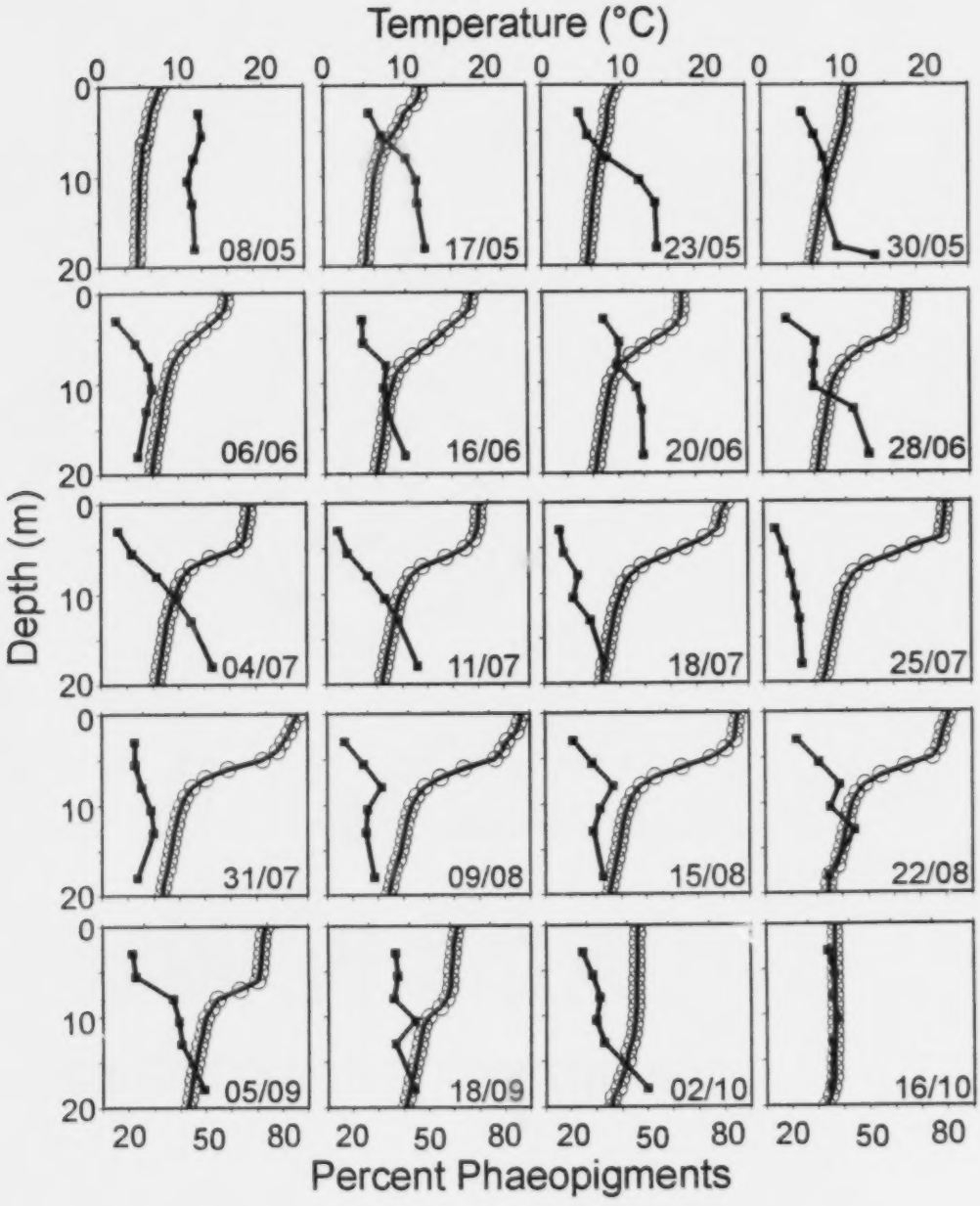

Figure 3.3: Vertical profiles of water temperature (○) and the percentage of phaeopigments in total chlorophyll *a* concentration (■) in Amisk Lake, 1989.

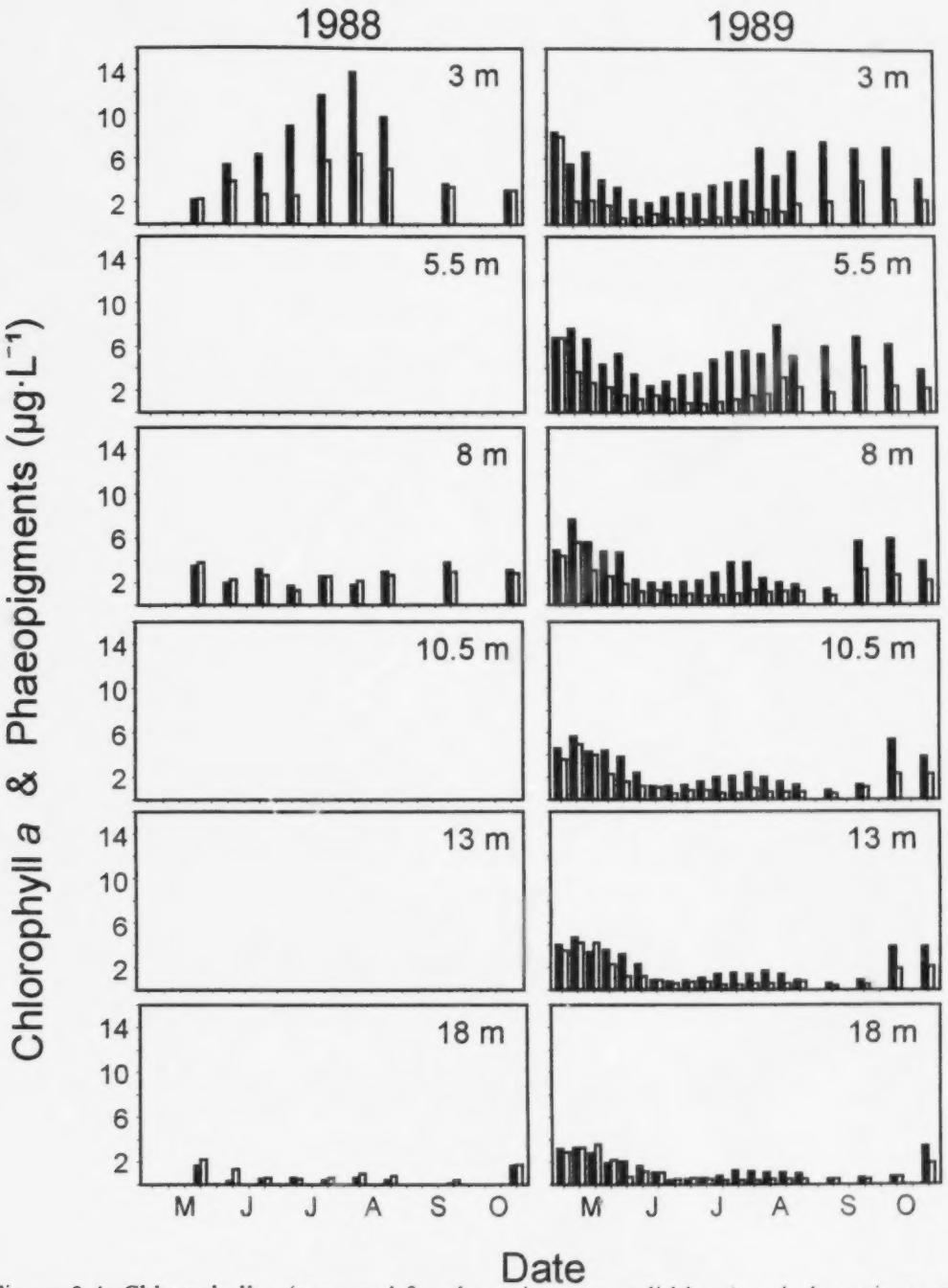

Figure 3.4: Chlorophyll *a* (corrected for phaeopigments; solid bars) and phaeopigment concentrations (empty bars) at each sampling depth in Amisk Lake, 1988 and 1989. Blank graphs indicate no data.

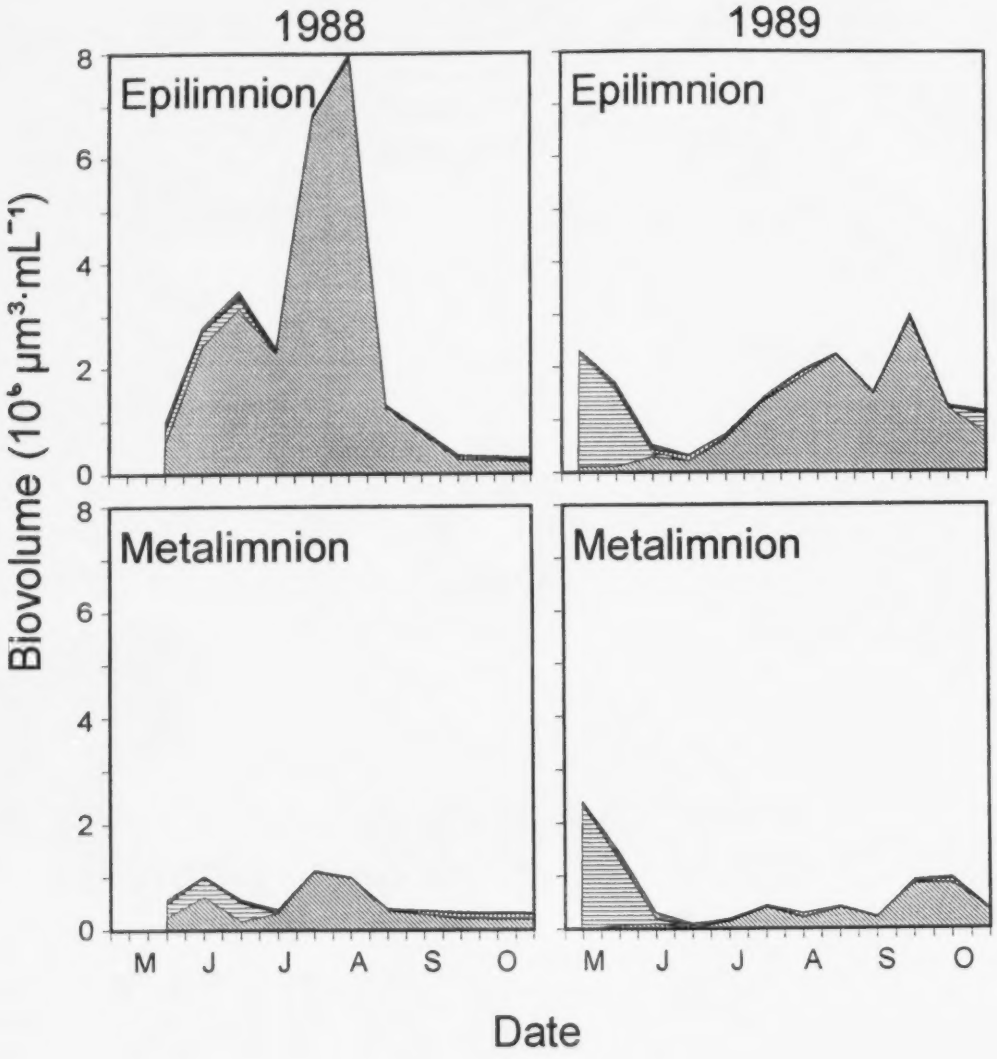

Figure 3.5: Phytoplankton biovolumes in the epilimnion and metalimnion in Amisk Lake, 1988 and 1989. Diagonal lines = cyanobacteria; horizontal lines = diatoms; vertical lines = green algae; shaded area = cryptophytes.

4. Influence of extended water column mixing in spring on the phytoplankton community in "naturally" eutrophic Amisk Lake, Alberta[2]

4.1 Introduction

Hypolimnetic aeration has been employed to increase hypolimnetic dissolved oxygen concentrations [DO] and thus improve water quality in a variety of eutrophic lakes and reservoirs. Many of the studies have been done in culturally eutrophic to hyper-eutrophic systems (Steinberg and Arzet 1984; McQueen and Story 1986; Bürgi and Stadelmann 1991; Ravera 1991; Simm 1991), but some studies have also been done on lakes which are naturally eutrophic (Fast et al. 1973; LaBaugh 1980; Ashley 1982). Most of these lakes were treated by introducing compressed air (or aerated water) into the deep, oxygen-poor water of the hypolimnion; few lakes have been treated by hypolimnetic injection of oxygen (hypolimnetic oxygenation).

Amisk Lake is the site of a whole-lake, hypolimnetic oxygenation study. It is a moderate-sized, relatively deep lake (surface area = 5.2 km^2, mean depth = 15.5 m) in an undeveloped drainage basin (88% forested, 4% agriculture, 8% lakes, muskeg and recreational development; Prepas 1990). There are virtually no anthropogenic point source inputs of nutrients, unlike many lakes that have undergone hypolimnetic aeration (for example, Steinberg and Arzet 1984; Bürgi and Stadelmann 1991; Simm 1991). Compared to many other culturally undisturbed lakes, Amisk Lake is relatively productive (mean summer euphotic [Chl *a*] was 17 (±2) $\mu g \cdot L^{-1}$ for seven years between 1980 and 1987; Prepas 1990). For example, of the 40 "pristine" lakes described in Armstrong and Schindler (1971), maximum euphotic [Chl *a*] recorded was < 10 $\mu g \cdot L^{-1}$ in 37 lakes, and ≤ 5 $\mu g \cdot L^{-1}$ in 28 of these lakes. Thus Amisk Lake offered a unique opportunity to study the effect of hypolimnetic oxygenation on the phytoplankton community of a naturally eutrophic lake.

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[2]A version of this chapter has been submitted for publication. D. J. Webb, R. D. Robarts, and E. E. Prepas. 1993. Can. J. Fish. Aquat. Sci.

Phytoplankton species succession during the open-water season was studied to evaluate the impact of hypolimnetic oxygenation. In temperate eutrophic lakes, dominance in the phytoplankton community typically shifts from diatoms and cryptophytes to green algae to cyanobacteria as the open-water season progresses (Wetzel 1983). Changes in nutrient concentrations, water temperature, turbulence of the water column, photosynthetically active radiation (PAR), and/or zooplankton grazing pressure may contribute to seasonal succession of phytoplankton species (Knoechel and Kalff 1975; Lastein and Gargas 1978; Hickman 1979; Smith 1983; Tilman et al. 1986; Vanni and Temte 1990). Turbulence within the water column is particularly important to diatom populations, which rely on external forces to remain in the euphotic zone: once the water column is thermally stratified, diatom cells which settle out of the epilimnion cannot return and thus descend to the lake bottom (Knoechel and Kalff 1975; Kalff and Knoechel 1978). Hypolimnetic oxygenation may alter the relationships among any or all of these controlling factors and thus affect phytoplankton species succession.

Determination of [Chl *a*] is a standard method of estimating primary production and trophic status in water bodies, and serves as an integrating tool in the study of phytoplankton. [Chl *a*] fluctuates throughout the open-water season in a lake, and may also differ from one part of the lake to another on any given date. Large lakes (with bays or basins that do not mix completely with the main water body), and lakes with point source nutrient inputs often exhibit horizontal heterogeneity of [Chl *a*] and phytoplankton (Glooschenko et al. 1972; Jones 1977; Nusch and Koppe 1981). Vertical heterogeneity of [Chl *a*] is often reported in productive, thermally stratified lakes (Rai 1975; Moll et al. 1984; Meffert and Overbeck 1985; Zohary and Robarts 1989), with phytoplankton concentrated in the portion of the epilimnion where light conditions are favourable for photosynthesis. In less productive thermally stratified lakes, the euphotic zone may extend below the epilimnion, and [Chl *a*] peaks may also occur in the upper hypolimnion (Fee 1978).

To evaluate the effect of hypolimnetic oxygenation on the phytoplankton community of Amisk Lake, physical and chemical data from the two years of this study (1988 and 1989) were compared to data collected during seven pretreatment years (1980-1987) from Amisk Lake, as well as to data from several other deep lakes in Alberta; phytoplankton data collected in 1988 and 1989 were compared to data collected in 1984 from Amisk Lake. [Chl *a*] patterns during the first full year of treatment (1989) were compared to patterns during the transition period (1988) as an indication of the extent to which the phytoplankton community was influenced horizontally and vertically by hypolimnetic oxygenation throughout the open water season. Based on this information, I tested the following hypotheses for a deep, naturally eutrophic lake with virtually no external phosphorus inputs: 1) hypolimnetic oxygenation will result in a decrease in mean [Chl *a*] during the open-water season (I anticipated that treatment would result in a reduction in the phosphorus released from the sediments); 2) hypolimnetic oxygenation will result in lower [Chl *a*] in the treated basin than in the untreated basin; 3) Chl *a* will be distributed deeper in the water column as a result of treatment (decreased [Chl *a*] in the epilimnion will result in a deeper euphotic zone and thus growth of phytoplankton within the metalimnion or upper hypolimnion); and 4) based on background literature, the dominant phytoplankton would shift from cyanobacteria to green algae for at least a portion of the open-water season.

4.2 Background and Methods

The Study Lake

Amisk Lake (54°35' N, 112°37' W) is located on the western edge of the Beaver River drainage basin in the boreal forest of central Alberta. The lake is long and narrow (on average, 8 x 0.6 km), with two basins (north basin surface area = 2.33 km^2, maximum depth = 34 m; south basin surface area = 2.82 km^2, maximum depth = 60 m; Prepas 1990; Fig. 4.1). Rolling hills surround the lake and provide protection from the wind, and as a result, the water column did not mix completely after ice-out

in three out of the five years between 1980 and 1987 for which spring water temperature data are available (E. E. Prepas, unpubl.). Amisk Lake lies in the Dry Mixedwood subregion of the Boreal Mixedwood Ecoregion of Alberta (Strong and Leggat 1981). Mean annual lake evaporation is 636 mm, while mean annual precipitation is 517 mm (Prepas 1990), with maximum precipitation in this ecoregion usually occurring in July (Strong and Leggat 1981). The upland areas around Amisk Lake may receive greater than the average amount of precipitation for the ecoregion as a whole, but much of this moisture is intercepted by forest vegetation, muskegs and soil: although the ratio of drainage basin area to lake surface area is 45:1, Amisk Lake receives little surface run-off on an annual basis (Prepas 1990). Surface inflow to Amisk Lake is intermittent, and water residence time is fairly long (at least 8 yr) (Prepas 1990). Therefore, most phosphorus input to the euphotic zone is from bottom sediments, a process which is accelerated when the overlying water is anoxic (Mitchell and Prepas 1990).

Amisk Lake has been studied every year since 1980 (with the exception of 1983) by researchers from the University of Alberta. (All further references to historical data, as well as to winter data (1988-89), data from the stratum extending from the lake surface to a depth of 6 m, and all data from depths greater than 18 m are from E. E. Prepas (unpubl.), unless otherwise indicated.) Historically, the euphotic zone was approximately the same depth as the epilimnion, with peak [Chl *a*] typically occurring near the bottom of the epilimnion. Between 1980 and 1987, mean summer [TP] and [Chl *a*] in the euphotic zone were 32 (±2) and 17 (±2) $\mu g \cdot L^{-1}$, respectively (Table 4.1), indicating a eutrophic lake (Wetzel 1983). Prior to hypolimnetic oxygenation, inorganic nitrogen concentrations in the hypolimnion were consistent with the development of anoxic conditions over the bottom sediments during the summer months. For example, by early August 1987, nitrate + nitrite concentration ($[NO_3]$) had declined to < 10 $\mu g \cdot L^{-1}$ at depths of 30 and 50 m in the north and south basins, respectively, while ammonium concentrations ($[NH_4]$) had increased to > 400 $\mu g \cdot L^{-1}$ at depths of 30 and 50 m in the north and south basins, respectively. Historical phytoplankton species data are limited to 1984, and indicate dominance by diatoms

and cryptophytes in spring, cyanobacteria in early summer, and pyrrhophytes and cyanobacteria in late summer (Prepas 1990). However, 1984 was atypical in that the water column mixed in the spring. The dominant zooplankton in the epilimnion before and during the early treatment years included *Daphnia galeata mendotae*, *D. pulex*, *Skistodiaptomus oregonenesis*, *Acanthocyclops vernalis*, and *Diacyclops bicuspidatus thomasi*, while dominant species in the hypolimnion included *Daphnia longiremis*, *D. pulex*, *Bosmina longirostris*, and *Diacyclops bicuspidatus thomasi* (Field and Prepas 1993). The benthic invertebrate community was dominated by *Chironomus* spp., other chironomids, *Chaoborus* spp. and Oligochaeta (Dinsmore and Prepas 1993). Yellow perch (*Perca flavescens*) and cisco (*Coregonus artedi*) dominated the littoral and pelagic fish communities, respectively (Aku et al. 1993).

Oxygen is injected into Amisk Lake through a diffuser, located just above the bottom sediments at site N2, the deepest part of the north basin (Fig. 4.1). Oxygen injection began 1 June 1988 and continued throughout the two years of this study (1988 and 1989). The rate of injection during thermally stratified periods generally ranged from 0.75 to 1 $t \cdot d^{-1}$ (except for five periods of 1 to 2 d and one of 5 d, when the system was inoperative due to technical problems), and from 0.35 to 0.6 $t \cdot d^{-1}$ when the water column was mixed (except for two periods of 1 to 2 d, due to technical problems).

Sample Collection

Water temperature and vertical stability, PAR, and nutrient concentrations (total phosphorus [TP], inorganic and organic nitrogen, and soluble reactive silica [Si]) were monitored to indicate which factor(s) was correlated with phytoplankton biovolume and species succession, and if this relationship was altered by the treatment. In 1988, samples were collected biweekly from 24 May to 15 August, and monthly in September and October (for a total of nine sampling dates). In 1989, samples were collected weekly from 8 May to 22 August, and bimonthly in September and October (for a total of 20 sampling dates). Site S1, located in the south basin, was chosen as a

reference site for comparison to N2, since the two sites have similar maximum depths (31 and 34 m, respectively; Fig. 4.1). Data were also collected at four additional sites for this study (N1 and N3 in the north basin, and S2 and S3 in the south basin; Fig. 4.1).

Temperature and underwater light penetration (PAR and Secchi depth) were measured at sites N2 and S1 in 1988, and at all six sites in 1989. Temperature was recorded at 1-m intervals from the water's surface to the bottom sediments with a Montedoro-Whitney resistance thermometer (model TC-5C). PAR was determined at 1-m intervals from the water's surface to below the euphotic zone (i.e., below the depth to which 1% of PAR at the lake surface penetrated) with a Protomatic light meter (model 313-426-3655). Due to equipment failure in 1988, PAR was not measured from 4 July to 2 August, but depth of the euphotic zone (m) was estimated from Secchi depth (m), based on an empirical model (r = 0.62; df = 113; equation 4.1) developed from dates/sites during the two study years when both PAR and Secchi data were available:

$$\text{depth of euphotic zone} = 0.88 * \text{Secchi depth} + 4.86. \quad (4.1)$$

In 1989, some PAR profiles were measured with a Li-Cor Quantum light meter (model LI-185). Based on replicate data collected with the two meters on five dates (at five or six sites per date), the depths of the euphotic zone were not statistically different (paired t-test; t = 0.84; $P > 0.4$; n = 29). Therefore, euphotic zone depths determined with the two meters were considered similar, and used interchangeably.

In 1988, water was collected from depths of 3, 8, and 18 m for chemical analyses; in 1989, water was collected at depths of 3, 5.5, 8, 10.5, 13, and 18 m. Samples from 3 m represented the mid-epilimnion; samples from 5.5 m represented the lower epilimnion to upper metalimnion; samples from 8 m represented the mid- to lower metalimnion; and samples from 10.5, 13, and 18 m represented the upper to mid-hypolimnion. The exception to this sampling program was water collected for TP analysis in 1988, which was collected at 2-m intervals within each 6-m stratum and

pooled: 0-6 m represented the epilimnion; 6-12 m was considered the metalimnion; the mean of 12-18 m and 18-24 m represented the mid-hypolimnion. Historically, the euphotic zone was approximately the same depth as the epilimnion, so phytoplankton were concentrated in the upper 6 m of the water column. With hypolimnetic oxygenation, I anticipated that decreased epilimnetic [Chl *a*] might result in a deeper euphotic zone, and thus phytoplankton could thrive in the metalimnion or even the hypolimnion. Since I could not predict the extent to which the euphotic zone might increase, I selected one depth within each of the epilimnion, metalimnion, and mid-hypolimnion initially, and added the two upper hypolimnetic depths (10.5 and 13 m), as well as an additional epilimnetic/metalimnetic depth (5.5 m) in 1989. Samples from the middle of the hypolimnion (18 m) were collected as an indication of the amount of intact phytoplankton that was potentially available to hypolimnetic zooplankton populations (Lean et al. 1987). Substantial [Chl *a*] at this depth would also suggest removal of nutrients from the euphotic zone as intact phytoplankton cells settled through the water column. Because this study focused on the phytoplankton, I concentrated on the physical, chemical, and biological parameters in the epilimnion and metalimnion (and to a lesser extent in the upper to mid-hypolimnion), where the phytoplankton were most likely to be found.

Water was collected with a 1.5-L aluminum drop-sleeve water bottle (collecting chamber approximately 30 cm high). Water for analyses of [Chl *a*], [TP] and phytoplankton was placed in 1-L opaque polyethylene bottles; water for analyses of $[NO_3]$ and $[NH_4]$ was placed in 75-mL polystyrene bottles; water for analyses of total Kjeldahl nitrogen concentration ([TKN]) and soluble reactive silica concentration ([Si]) was placed in 300-mL polystyrene bottles. All water samples were stored in coolers with ice packs while in the field, then refrigerated at 4°C. All analyses were performed on samples collected on each date in both years, except that in 1989, samples for [TKN], [Si], and phytoplankton analyses were collected biweekly, samples for [TKN] and [Si] were only collected from 3, 8, and 18 m, and no samples for [TKN] or [Si] analysis were collected in October 1989. To determine if there were any [Chl *a*] peaks

situated between sampling depths, *in situ* fluorescence profiles were measured biweekly from 30 May to 22 August 1989 at N2 and S1 with a Turner Designs Field Fluorometer (model 10-005).

The open-water season was divided into three distinct periods: 1) the spring and 2) fall mixed periods, during which there was no metalimnion (i.e., no zone of > 1°C change in temperature for every 1 m change in depth; Wetzel 1983), and 3) the thermally stratified period, during which the metalimnion was well-defined. The ice left Amisk Lake on 23 April in 1988, and according to water temperature profiles, thermal stratification was established prior to 16 May (E. E. Prepas, unpubl.), indicating there was little or no spring mixed period in 1988. Thus the thermally stratified period included sampling dates from 24 May to 20 September 1988, and the fall mixed period was represented by 18 October. In 1989, the lake was ice-free by 3 May. The spring mixed period included sampling dates from 8 to 30 May 1989, the thermally stratified period from 6 June to 18 September, and the fall mixed period from 2 to 16 October.

Sample Analyses

[TP], [NO_3], and [NH_4] analyses were done on triplicate subsamples. After filtration through a 243-μm Nitex net to remove large plankton, [TP] was determined according to Menzel and Corwin's (1965) potassium persulfate method as modified by Prepas and Rigler (1982). Samples were analyzed for [NO_3] (after filtration through 0.45-μm HAWP Millipore membrane filters) and [NH_4] (unfiltered) on a Technicon AutoAnalyzer (Stainton et al. 1977; Solorzano 1969, respectively). Analyses of [TP], [NH_4], and [NO_3] were usually done within 24 h of sample collection. [Si] and [TKN] analyses were performed at the National Water Research Institute (Environment Canada 1979). (All further references to [Si] and [TKN] are from T.P. Murphy, unpubl.). Total nitrogen concentration ([TIN]) was calculated as the sum of [TKN] and [NO_3]; total inorganic nitrogen concentration ([TIN]) was calculated as the sum of [NH_4] and [NO_3]. [TN] to [TP] ratio (TN:TP) was calculated to evaluate the potential for nitrogen limitation.

Determination of [Chl *a*] was based on Nusch's (1980) ethanol extraction method. Two 300-mL subsamples from each sample were filtered through GF/C filters at -50 kPa. In 1988, samples were stored overnight and filtered the following day, but in 1989, samples were filtered immediately upon return to the laboratory. The filters were folded and placed in foil-wrapped plastic petri dishes with tight-fitting lids. The filters were then frozen for up to 3 wk before further analysis. After extraction in 90% ethanol, absorbances were read with a Milton Roy Spectronic 1001 spectrophotometer (8-mL cell, 10-cm path length, 2-nm slit width) at 750 and 665 nm. The spectrophotometer was calibrated with a pure Chl *a* extract standard (Sigma Chemicals, St. Louis, MO), and the appropriate correction factor was applied to concentrations based on Nusch's (1980) equations. All Chl *a* samples were prepared and analyzed under low, incandescent light conditions. Although phaeopigment concentrations were determined by acidifying each extract, total [Chl *a*] (i.e., not corrected for phaeopigments) were used for this study so that comparisons could be made between [Chl *a*] measured during the early years of oxygenation and historic [Chl *a*] (which were not corrected for phaeopigments). Therefore, [Chl *a*] refers to total [Chl *a*] (i.e., no correction for the presence of phaeopigments) for the remainder of this chapter.

Phytoplankton samples were analyzed according to Lund et al.'s (1958) inverted microscope technique. Phytoplankton cells were usually identified to genus (but sometimes to species), and enumerated. At least 10 representative cells from each taxon were measured on at least three dates in each year so that cell volumes could be calculated, based on the closest geometric shape.

[Chl *a*] for each sample was based on the average of two subsamples; mean [Chl *a*] was then calculated for each pair of replicate samples from each depth at each site. Variation between replicate samples was very low, with a mean coefficient of variation of 4% (Table 4.2). There were five unreplicated samples in 1989. These unreplicated values (based on subsample [Chl *a*]) were included with the 871 mean [Chl *a*] for subsequent statistical analyses. Thus n = 162 in 1988 (3 depths x 6 sites x

9 dates); in 1989 six pairs of replicate samples were lost, so n = 714 (6 depths x 6 sites x 20 dates - 6 lost samples). Statistical analyses of [Chl *a*] were performed with the Statistical Analysis System (SAS) on a PC computer. Analyses of variance (ANOVA's) and Student-Newman-Keuls (SNK) tests were performed to determine if [Chl *a*] varied among dates, among depths, and/or among sites in each year. Whole-lake mean values were calculated for each parameter at each sampling depth for each sampling date (unless otherwise indicated). In 1989, the mean value of data from 3 and 5.5 m was considered representative of the epilimnion. (Although 5.5 m was within the upper metalimnion on a number of dates during the 1989 thermally stratified period, the values of the different parameters at a depth of 5.5 m were more similar to values from 3 m than to values from 8 m, so data from 5.5 m was included with epilimnetic data.) The terms "epilimnetic", "metalimnetic", and "mid-hypolimnetic" refer to the corresponding sampling depths during periods of mixing as well as during periods of thermal stratification. For both years, data were weighted according to frequency of their collection (i.e., weekly, biweekly, or monthly) for calculation of seasonal means (±*SE*).

4.3 Results

Physical and Chemical

I considered 1988 a transition period between pre-treatment years and the first full year of treatment (1989), since oxygenation did not begin until midway through the 1988 open-water season, by which time thermal stratification was well-established. Amisk Lake was thermally stratified for the first eight out of nine sampling dates in 1988 (Fig. 4.2). The epilimnion extended to a depth of 6 (±0.5) m during this period (Fig. 4.3). Maximum recorded temperature at the water surface during the 1988 thermally stratified period was 21°C. During the 1988 fall mixed period, the upper 18 m of the water column at both sites (N2 and S1) was isothermal, while temperature decreased from 10 to 9°C, and from 6 to 5°C between a depth of 19 m and the deepest depth in the north and south basins, respectively. In 1989, the upper 18 m of the lake was mixed at the beginning and end of the open-water season (Fig. 4.4). On

the first date of the 1989 spring mixed period, the temperature gradient was 2 and 4°C between the surface and the deepest depth in the north and south basins, respectively. During the 1989 thermally stratified period, maximum recorded surface water temperature was 24°C; the epilimnion extended to 4 (±0.3) m during this period (Fig. 4.3). By the end of the 1989 fall mixed period, water temperature was isothermal from the surface to the deepest depth in the north basin; the upper 18 m of the water column in the south basin was isothermal, and decreased to a minimum of 5°C at the deepest depth. Thus in 1989, phytoplankton experienced a greater range of water temperatures near the lake's surface, as well as a shallower epilimnion, than in 1988.

The euphotic zone extended below the mixed zone on all but the final two dates in the thermally stratified period of 1988, and on all but the final date during the same period in 1989. During the thermally stratified period in 1988 and 1989, mean depth of the euphotic zone was 7.2 (±0.2) m and 7.6 (±0.3) m, respectively (Fig. 4.3). On these dates, the upper portion of the nutrient-enriched metalimnion was sufficiently illuminated for net primary production, and phytoplankton growth throughout the epilimnion was probably not light-limited during daylight hours of this study.

[TP] in the epilimnion and metalimnion reflected the absence or presence of a spring mixed period in each year. In 1988, [TP] in these strata was relatively constant from the beginning of the open-water season to the end of the thermally stratified period (Fig 4.5; Table 4.3). During the 1989 spring mixed period, epilimnetic and metalimnetic [TP] were considerably higher than during the thermally stratified period of either 1988 or 1989, indicating that TP had accumulated in the hypolimnion under ice and was mixed upward in the water column at this time; [TP] was relatively constant during the 1989 thermally stratified period (Fig. 4.5; Table 4.3). Mid-hypolimnetic [TP] generally increased throughout the thermally stratified period in both 1988 and 1989. Mean volume-weighted summer [TP] in the entire hypolimnion was lower in 1989 than in 1988, and lower in the north basin than in the south during both years (north = 96 (±4) and 80 (±10) $\mu g \cdot L^{-1}$ in 1988 and 1989, respectively; south = 106 (±4) and 86 (±9) $\mu g \cdot L^{-1}$ in 1988 and 1989, respectively). These values are lower than the equivalent historical [TP] of 123 (±8) and 128 (±8) $\mu g \cdot L^{-1}$ in the north and

south basins, respectively. The decline in hypolimnetic [TP] in both basins suggests that increased [DO] suppressed TP release from hypolimnetic sediments; measurements of currents in the channel connecting the two basins and increased [DO] in the south basin were consistent with DO transfer from the north basin to the south basin (Lawrence et al. ms. submitted). Based on mean summer [TP] (29 and 22 $\mu g \cdot L^{-1}$ in 1988 and 1989, respectively) in the stratum from the surface to a depth of 6 m, the trophic status of Amisk Lake decreased from the historic eutrophic condition to mesotrophic (Wetzel 1983) during the first two years of oxygen treatment.

Epilimnetic and metalimnetic [TIN] were considerably lower throughout the open-water season of both years (as well as historically) than typical epilimnetic [TIN] for mesotrophic (300 to 650 $\mu g \cdot L^{-1}$) or eutrophic (500 to 1500 $\mu g \cdot L^{-1}$) lakes (Wetzel 1983; Fig. 4.5; Table 4.3). Low [TIN] suggests rapid uptake and assimilation by phytoplankton (Wetzel 1983), and/or low internal input rates for NO_3 and NH_4. Mid-hypolimnetic [NO_3] patterns were different between the two years: in 1988, [NO_3] reached its peak early in the thermally stratified period and then declined, while in 1989, [NO_3] generally increased throughout the thermally stratified period, reaching its maximum near the end of the period. Mean [NO_3] at a depth of 30 m was similar at site N2 during the thermally stratified period in 1988 and 1989 (161 (±62) and 151 (±87) $\mu g \cdot L^{-1}$, respectively), but was much greater at site S1 in 1989 than in 1988 (191 (±113) and 20 (±25) $\mu g \cdot L^{-1}$, respectively). Epilimnetic and metalimnetic [NH_4] were similar between basins throughout both years. However, [NH_4] is the only parameter measured in this study that was noticeably different between the two basins in the mid-hypolimnion, and only in 1988. In 1988, mid-hypolimnetic [NH_4] was similar in both basins during the first part of the thermally stratified period, after which [NH_4] at site N2 remained relatively low but [NH_4] increased continually at site S1 to a maximum of 257 $\mu g \cdot L^{-1}$ on the last sampling date. In contrast, mid-hypolimnetic [NH_4] was similar in the two basins throughout the 1989 thermally stratified period, and was generally lower than in 1988. As with [NO_3], [NH_4] at the bottom of the hypolimnion were consistent with improved [DO] by 1989: mean [NH_4] at a depth of 30 m was over two-fold greater at site S1 than at site N2 in 1988 (372 (±119) and 127 (±46)

$\mu g \cdot L^{-1}$, respectively), but mean [NH_4] was similar at sites S1 and N2 in 1989 (179 (±79) and 190 (±89) $\mu g \cdot L^{-1}$, respectively). This pattern of [NO_3] and [NH_4] reflects similar [DO] at a depth of 30 m in the two basins after one full year of oxygenation.

The mean proportion of [TN] contributed by organic nitrogen during the open-water season of 1988 and 1989 ranged from 99.7% (±0.1%) and 99.9% (±0.1%), respectively, in the epilimnion, to 82.4% (±3.1%) and 84.1% (±1.7%), respectively, in the mid-hypolimnion (for dates on which both inorganic and organic nitrogen data were available). Mean [TKN] were slightly higher during the 1988 thermally stratified period than in the same period in 1989 at all depths (Fig. 4.5; Table 4.3). Mean [TKN] at a depth of 30 m was 0.90 (±0.08) $mg \cdot L^{-1}$ during the 1988 thermally stratified period, and 0.79 (±0.02) $mg \cdot L^{-1}$ during the same period in 1989. Historically, epilimnetic [TKN] ranged from 1.0 to 1.5 $mg \cdot L^{-1}$, and [TKN] at 30 m ranged from 1.2 to 1.4 $mg \cdot L^{-1}$; reduction in [TKN] during the study suggests the quantity of organic matter in the water had declined with hypolimnetic oxygenation.

A TN:TP ratio in the epilimnion of < 29:1 is considered an indication of nitrogen deficiency; cyanobacteria tend to be the dominant phytoplankton at lower ratios, while at higher ratios, cyanobacteria are expected to be rare (Smith 1983). During the 1988 thermally stratified period, epilimnetic TN:TP ratio was between 30:1 and 38:1 on all but the first date, while during the same period in 1989, the ratio was higher (38:1 to 51:1). Based on Smith's (1983) predictions, the epilimnion of Amisk Lake was not nitrogen-deficient, and cyanobacteria should have been rare during the thermally stratified period in both years. However, cyanobacteria were, in fact, the dominant phytoplankton, and some cyanobacteria possessed heterocysts. Throughout the 1988 thermally stratified period, and on all but the first date of this period in 1989, < 1% of epilimnetic *Anabaena flos-aquae* cells were heterocysts. Among *Aphanizomenon flos-aquae*, 20% (±12%) and 28% (±21%) of filaments had heterocysts during the thermally stratified period in 1988 and 1989, respectively. Therefore, even though the TN:TP ratio did not indicate nitrogen deficiency (according to Smith (1983)), the presence of heterocysts indicates that nitrogen fixation had

occurred, which is consistent with low inorganic nitrogen concentrations in Amisk Lake.

Si is essential in the construction of frustules for all diatom species. In both years, epilimnetic [Si] decreased to < 0.5 $mg \cdot L^{-1}$ part way through the thermally stratified period (Fig. 4.5; Table 4.3). Minimum epilimnetic [Si] was lower in 1989 than in 1988 (0.2 and 0.4 $mg \cdot L^{-1}$, respectively). Metalimnetic and mid-hypolimnetic [Si] remained > 2.0 $mg \cdot L^{-1}$ throughout both study years. Mid-hypolimnetic [Si] was higher during the 1989 thermally stratified period than during the spring mixed period, suggesting Si transfer from the epilimnion to the hypolimnion with time. Diatom growth was likely not limited by low [Si] when the water column was well mixed. However, based on Lund's (1950) lower limit of 0.5 $mg \cdot L^{-1}$ for *Asterionella formosa*, [Si] in the epilimnion was at a critical level for at least some species of diatoms during part of the thermally stratified period in both years, and especially in 1989.

Chl a

Horizontal patterns of [Chl *a*] did not vary consistently during either year (i.e., [Chl *a*] was not always higher at some sites than at others throughout the open-water season). As a result, [Chl *a*] was not consistently different among sites in either 1988 or 1989 (Table 4.4; SNK; df = 136 and 659, respectively; $P > 0.05$). Timing of the maximum difference in [Chl *a*] among sites corresponded to maximum mean [Chl *a*] for the open-water season. During the open-water season of 1988, there was 1.1- to 1.8-fold variation in epilimnetic [Chl *a*] among sites on any given date (mean variation = 1.4- ($\pm$0.1) fold); during the open-water season of 1989, among-site variation in epilimnetic [Chl *a*] was from 1.1- to 2.8-fold on any given date (mean variation = 1.5- ($\pm$0.1) fold). Variation of this magnitude in [Chl *a*] among all sites is similar to historical horizontal variation in Amisk Lake: on 28 May 1980, euphotic [Chl *a*] ranged from 6 to 12 $\mu g \cdot L^{-1}$ (i.e., a 2-fold difference) among seven pelagic sites. Difference in mean summer [Chl *a*] between the north and south basins in the stratum from the surface to a depth of 6 m was 0.1 and 0.5 $\mu g \cdot L^{-1}$ in 1988 and 1989,

respectively, which is small when compared to historic between-basin differences of 2.7 (±0.7) $\mu g \cdot L^{-1}$. During this study, horizontal patterns of [Chl *a*] along the north-south axis of the lake did not consistently correspond to horizontal patterns of nutrient concentrations (TP, NO_3, NH_4, Si) or temperature, nor did [Chl *a*] patterns reflect prevailing wind direction and/or speed with any consistency. Because horizontal heterogeneity of [Chl *a*] was inconsistent, all subsequent analyses of vertical and temporal [Chl *a*] patterns were based on the whole-lake mean [Chl *a*] at each depth on each date. Since whole-lake mean concentrations were used to determine [Chl *a*] patterns, whole-lake mean values of the other parameters were used to determine the relationships among [Chl *a*], nutrient concentrations, temperature, euphotic zone depth, and phytoplankton species.

[Chl *a*] was usually highest in the epilimnion and lowest in the mid-hypolimnion during both years of the study, as reflected by the pattern of [Chl *a*] on each date as well as by the seasonal mean [Chl *a*] at each sampling depth (Fig. 4.5; Table 4.5). Mean [Chl *a*] for the entire open-water season was statistically different among sampling depths in both 1988 and 1989 (Table 4.4; SNK; df = 136 and 659, respectively; $P < 0.05$). Epilimnetic [Chl *a*] was greater than metalimnetic [Chl *a*] on most sampling dates in both 1988 and 1989, but on many dates in 1989, the difference in [Chl *a*] between these depths was small (i.e., < 1.5 $\mu g \cdot L^{-1}$ difference on 13 out of 20 dates; Fig. 4.5). Mean summer [Chl *a*] in the stratum extending from the surface to a depth of 6 m was lower in 1988 and 1989 (10.0 and 8.2 $\mu g \cdot L^{-1}$, respectively) than historic values (*t*-test; $t = 12.5$ and 12.4, respectively; $P < 0.05$). During this study, Chl *a* was not as restricted to the upper 6 m of the water column as it was historically: by 1989, metalimnetic [Chl *a*] was similar to or greater than epilimnetic concentrations throughout all of the open-water season except the latter part of the thermally stratified period (Fig. 4.5). In comparison, maximum [Chl *a*] was always measured at depths of between 1 and 6 m in 1982 (Prepas and Vickery 1984), while fluorescence profiles taken in 1985 indicated maximum [Chl *a*] at depths of < 5 m. Relatively high [Chl *a*] in the mid-hypolimnion during the 1989 spring mixed period and the early part of the

thermally stratified period suggest a greater food supply for hypolimnetic zooplankton than may have been available in the past.

On the seven dates in 1989 when fluorescence profiles were measured, no [Chl *a*] peaks were situated between sampling depths, and I assume these profiles were representative of the open-water season in 1989. However, [Chl *a*] was higher at a depth of 5.5 m than at 3 m on many of the dates in 1989, so I assume Chl *a* in the lower epilimnion may have been overlooked in 1988. Comparison between [Chl *a*] at 3 m and in the stratum from the surface to a depth of 6 m supports this assumption: on four out of nine sampling dates in 1988, [Chl *a*] at 0-6 m was greater than [Chl *a*] at 3 m (from 14% to 25% higher), which suggests that Chl *a* was concentrated elsewhere in the upper 6 m of the water column than at a depth of 3 m.

[Chl *a*] was not constant throughout the open-water season in either year: mean [Chl *a*] at all sampling depths was significantly different among dates, and followed the same general pattern through time as epilimnetic [Chl *a*] in each year (Fig. 4.5; Table 4.4 and 4.6). In 1988, epilimnetic [Chl *a*] increased from its seasonal minimum (4.5 $\mu g \cdot L^{-1}$) at the beginning of the thermally stratified period to its seasonal maximum (20.2 $\mu g \cdot L^{-1}$) near the middle of the period. In 1989, epilimnetic [Chl *a*] declined from its seasonal maximum (15.0 $\mu g \cdot L^{-1}$) at the beginning of the spring mixed period to its seasonal minimum (3.5 $\mu g \cdot L^{-1}$) near the beginning of the thermally stratified period, then gradually increased throughout the remainder of the latter period. Metalimnetic [Chl *a*] was at its seasonal maximum at or near the beginning of the open-water season in both 1988 and 1989 (7.3 and 13.3 $\mu g \cdot L^{-1}$, respectively). Mid-hypolimnetic [Chl *a*] was greater at the beginning and end of the open-water season than during the middle in both years. Change in the timing of the seasonal maximum [Chl *a*] from mid-season in 1988 to immediately after ice-out in 1989 suggests alterations in the phytoplankton community in 1989, including a large bloom of one or more species in response to mixed conditions in the spring, and delayed and reduced development of the dominant mid-summer species.

Phytoplankton Biovolume and Species Succession

Phytoplankton identified in 1988 and 1989 were from four groups: diatoms, cyanobacteria (blue-greens), green algae, and cryptophytes. Of these, cyanobacteria and diatoms were the most important groups in terms of cell biovolume. Twenty-seven taxa were identified in at least one sample during 1988 or 1989 (Table 4.7). Since phytoplankton cells in the mid-hypolimnion were likely viable only during periods of mixing, efforts to determine phytoplankton species succession focused on epilimnetic and metalimnetic populations.

Throughout 1988, cyanobacteria were the dominant phytoplankton in the epilimnion and metalimnion (Table 4.8). Peak phytoplankton biovolume at these depths were recorded mid-way through the thermally stratified period in 1988, with *Aphanizomenon flos-aquae* contributing > 20% of the phytoplankton biovolume at both depths on all dates in 1988, and diatoms (especially *Asterionella formosa* in the epilimnion) contributing > 20% of the biovolume at the beginning of the thermally stratified period.

Maximum phytoplankton biovolume was lower in 1989 than in 1988, and dominant taxa were more diverse in 1989 compared with the phytoplankton community in 1988 (Table 4.8). Phytoplankton biovolume in the epilimnion was relatively high at the beginning of the spring mixed period, although the peak biovolume was recorded on the last date of the thermally stratified period. Diatoms were important contributors to phytoplankton biovolume at all depths during the 1989 spring mixed period, with *Asterionella formosa* and *Cyclotella* spp. being the dominant taxa. Cyanobacteria were the dominant phytoplankton in the epilimnion and metalimnion during the 1989 thermally stratified and fall mixed periods (especially *Aphanizomenon flos-aquae* and *Anabaena flos-aquae*), with green algae (*Oocystis* sp.) and cryptophytes (*Cryptomonas* sp.) contributing up to 51% and 32%, respectively, of total phytoplankton biovolume early in the thermally stratified period, and diatoms (*Fragilaria* sp.) contributing 32% at the end of the fall mixed period. Metalimnetic phytoplankton biovolume was higher during the 1989 spring mixed period than it was

at any time during 1988, suggesting that as a result of the mixing, phytoplankton (i.e., diatoms) were present in greater volume in the metalimnion, at least for part of the open-water season, than in years in which thermal stratification is established immediately after the ice leaves the lake.

4.4 Discussion

Hypolimnetic oxygenation was associated with changes in the vertical stability of the water column, depth of the euphotic zone, and concentrations and vertical distribution of some nutrients in Amisk Lake; these changes contributed to alterations in phytoplankton species composition and distribution, and thus vertical and temporal patterns of [Chl *a*]. Effects of treatment were more obvious during 1989 (the first full year of oxygen injection), but some effects were also noted in 1988 (the transitional year).

Of all physical and chemical changes associated with the treatment, enhancement of deep-mixing of the water column in spring 1989 appeared to have the greatest impact on the phytoplankton community. Oxygen was injected into the lake throughout the winter of 1988-89. Because of the minimal temperature gradient between the top and bottom of the water column under the ice (from 0 to 3°C), a relatively low rate of oxygen injection was probably sufficient to maintain circulation under the ice (Ashley 1988). When the ice went out on 3 May 1989, deep-mixing of the water column was readily achieved, and an increase in the rate of oxygen injection immediately after ice-out delayed the development of thermal stratification until early June 1989. In contrast, oxygen was not injected before or immediately after ice-out in 1988, and wind action was insufficient to completely mix the water column, so the water column was thermally stratified almost immediately after ice-out. Although spring mixing can occur naturally in Amisk Lake (as in 1982 and 1984), hypolimnetic oxygenation appears to increase the frequency of occurrence of spring mixing: between 1980 and 1988, Amisk Lake mixed in only two out of six years for which spring temperature data are available, while between 1989 and 1992, the water column mixed in the spring in four out of four years (based on temperature and dissolved oxygen

concentration profiles; E. E. Prepas, unpubl.). Nearby Narrow Lake, which has similar morphometry to Amisk Lake (Prepas et al. 1988), also mixed in only two out of six years between 1980 and 1988 for which spring temperature data are available, but in Narrow Lake, spring mixing only occurred once in the four years between 1989 and 1992 (E. E. Prepas, unpubl.). Thus hypolimnetic oxygenation appears to have enhanced spring mixing in Amisk Lake.

Turbulent conditions in the water column in spring 1989 promoted a massive growth of diatoms, a component of the phytoplankton community that was relatively unimportant in spring 1988. Fast-growing, small-celled species (such as *Cyclotella* spp. and *Asterionella formosa*, which dominated the phytoplankton community in Amisk Lake in spring 1989) are favoured by well-mixed, nutrient-replete waters (Reynolds et al. 1987), possibly due to the cells' faster nutrient uptake rates (Friebele et al. 1978; Keating 1978). Thus in spring 1989, > 80% of the phytoplankton biovolume in the epilimnion and metalimnion was diatoms; in comparison, spring mixing did not occur in 1988, and cyanobacteria dominated the phytoplankton throughout the open-water season. This relationship between mixed conditions in the water column and development of a large spring diatom population has been recorded in nearby lakes: in Moore Lake, deep mixing did not occur in spring 1980 (at which time 76% of the phytoplankton biomass was cyanobacteria), but deep mixing and a large diatom population were recorded in spring 1981 (when 47% of the phytoplankton biomass was diatoms; Bradford 1990). Spring mixing accompanied by large spring diatom populations has been documented in at least 16 other mesotrophic to hyper-eutrophic lakes in Alberta, as well as in Amisk Lake in 1984 (Mitchell and Prepas 1990). In comparison, thermal stratification early in spring coincided with dominance of the phytoplankton by groups other than diatoms during the spring in at least six oligo-mesotrophic to hyper-eutrophic Alberta lakes (Mitchell and Prepas 1990). The predominance of diatom populations during periods of mixing has been reported in a variety of lakes outside of Alberta (Reynolds 1975; Parker et al. 1977; Jewson et al. 1981; Trimbee and Harris 1984). Therefore, growth of large populations of diatoms in Amisk Lake during spring 1989 was likely in response to deep-mixing of the water

column, which was enhanced by hypolimnetic oxygenation; treatment delayed establishment of thermal stratification and enabled the diatom community to persist for over 4 wk.

Complete mixing of the water column in spring 1989 brought nutrients (TP, NO_3, NH_4, and Si) that had accumulated in the hypolimnion during winter up to the euphotic zone, stimulating phytoplankton growth early in the open-water season. (However, the amount of TP released from bottom sediments under ice in 1988-89 and thus available to be mixed into the upper portion of the water column was less than during previous winters, due to improved oxygen conditions in the hypolimnion as a result of oxygenation.) The spring diatom bloom, in turn, impacted nutrient concentrations (especially [TP] and [Si]) in the euphotic zone, and thus the phytoplankton community during the remainder of the 1989 thermally stratified period. With the onset of thermal stratification, diatoms no longer had the turbulent conditions necessary to remain in the euphotic zone, so the cells settled downward, removing TP and Si (bound up in cell components) from the upper portion of the water column. This removal of nutrients is evident in the dramatic decrease in epilimnetic and metalimnetic [TP] at the beginning of the 1989 thermally stratified period, and the continued decline of epilimnetic [Si] throughout the first half of the period. Physical conditions were suitable for development of a cyanobacterial bloom during the remainder of the 1989 thermally stratified period (i.e., well-defined epilimnion, increasing water temperature), but maximum phytoplankton biovolume was likely constrained by the amount of TP present in the epilimnion at the beginning of this period in 1989, as well as in 1988. However, there was no spring mixed period in 1988, no spring diatom bloom, and no subsequent removal of nutrients from the epilimnion; thus epilimnetic and metalimnetic [TP] were greater throughout the 1988 thermally stratified period than during the same period in 1989. Removal of nutrients from the euphotic zone via settling diatoms, combined with a reduced amount of TP released from the bottom sediments under ice, contributed to a 50% reduction in the amplitude of peak cyanobacterial biovolume during the 1989 thermally stratified period compared to the same period in 1988.

Diatoms provide many benefits over cyanobacteria in terms of lake management. Freshwater diatoms produce no known toxins, whereas cyanobacteria produce an array of hepato- and neurotoxins (Kotak et al. 1993). Diatoms settle out of the euphotic zone once thermal stratification is established, transporting nutrients into the hypolimnion and thus reducing the amount of nutrients available for subsequent phytoplankton populations; cyanobacteria cells lyse and may release nutrients within the epilimnion (Gunnison and Alexander 1975). Diatoms do not form the floating mats of cells that some cyanobacteria produce (Zohary and Robarts 1989). Finally, diatoms are a more desirable food source than cyanobacteria for zooplankton (Porter 1973; Vanni and Temte 1990). If the limited amount of TP in Amisk Lake can be channelled into diatom growth rather cyanobacterial growth, improved food quality (i.e., diatoms) will likely lead to increased zooplankton biomass and thus increased planktivorous fish biomass.

Hypolimnetic oxygenation shifted the seasonal species succession of phytoplankton in Amisk Lake towards an extended spring diatom bloom. However, missing from the seasonal succession was the green algal peak which is reported to be a typical interlude between the spring diatom bloom and cyanobacterial dominance in summer in temperate eutrophic lakes (Wetzel 1983). (Although green algae made substantial contributions early in the 1989 thermally stratified period, total phytoplankton biovolume at this time was very low, and could not be considered a "peak".) Large populations of green algae are noticeably absent in summer from eutrophic Alberta lakes. For example, the phytoplankton communities of 26 freshwater Alberta lakes were reported in Mitchell and Prepas (1990): green algae contributed $\leq$ 20% of the phytoplankton biomass in 20 out of the 26 lakes on any date during the summer months (June - August), and > 30% in only two of these lakes. The relative obscurity of green algae in Amisk Lake (and many other lakes in Alberta) during the summer may be due to very low [TIN] in the epilimnion (usually < 5 $\mu g \cdot L^{-1}$ in Amisk Lake). Since many species of cyanobacteria can fix atmospheric nitrogen, cyanobacteria would be expected to dominate when [TIN] is low. The increase in green algae reported in other hypolimnetic aeration studies (Bürgi and Stadelmann

1991; Simm 1991) may thus be related to the availability of TIN. Addition of a large quantity of nitrogen (mainly NH_4) enhanced the growth of green algae and suppressed the cyanobacterial bloom in a hyper-eutrophic prairie pond (Barica et al. 1980); treated lakes in which green algal growth was stimulated were, in fact, nitrogen-rich (Simm 1991). Hypolimnetic oxygenation in Amisk Lake resulted in a decrease in hypolimnetic [NH_4], and thus a decrease in TIN that migrated to the euphotic zone, so green algae were even more nitrogen-limited than before treatment. Therefore, the continued absence of a green algal peak during hypolimnetic oxygenation in Amisk Lake was not unexpected.

Besides altering phytoplankton species succession, hypolimnetic oxygenation led to a downward extension of the vertical profile of [Chl *a*] in Amisk Lake. Historically, the euphotic zone extended to a depth of 6 m or less. In 1988 and 1989, the euphotic zone had increased to 7.2 and 7.6 m, respectively, probably as a result of decreased [Chl *a*] in the epilimnion. With the euphotic zone extending below the mixed zone on most dates in the thermally stratified period of both years, phytoplankton were able to grow at depths within the metalimnion, as indicated by relatively high metalimnetic [Chl *a*] on a number of dates. Increased abundance of phytoplankton at deeper depths (especially diatoms) suggests a greater food source for zooplankton in the metalimnion and upper hypolimnion, which should then lead to an improved resource base for planktivorous fish at these depths.

Hypolimnetic oxygenation did not alter the horizontal patterns of [Chl *a*] in Amisk Lake (although the overall amount of between-basin variation declined): as in the past, [Chl *a*] in one basin was not consistently lower than in the other basin. Relatively small amounts of among-site variation in [Chl *a*] (less than 3-fold) on any given date in Amisk Lake during this study (and historically) reflects the absence of point-source (anthropogenic and natural) inputs of nutrients, as well as the degree of horizontal mixing afforded by the lake's long, narrow shape and its parallel alignment with prevailing wind direction. Currents produced by hypolimnetic oxygenation probably enhanced horizontal mixing activity. In comparison, nearby hyper-eutrophic

Baptiste Lake has two distinct basins separated by a narrow, shallow channel, and likely more direct and/or indirect input of nutrients from anthropogenic sources: surface [Chl *a*] varied over 30-fold among sites on 6 July 1976 (Trew et al. 1987). In Amisk Lake, difference between basins in mean summer [Chl *a*] in the upper 6 m of the water column was relatively low historically; however, reduced primary productivity and increased mixing as a result of hypolimnetic oxygenation decreased the amount of between-basin variation even further during the two years of the study. Although oxygen was only injected into one basin, the benefits of treatment appear to have been spread throughout the pelagic region of the entire lake.

Control of phytoplankton has been more successful in Amisk Lake than in many other studies involving hypolimnetic aeration, largely because external TP inputs were minimal, and because deep-mixing of the water column in spring was successfully induced. Oxygenated, as opposed to anoxic water, overlying the sediment-water interface appears to have inhibited sediment TP release. Less TP was available to be distributed throughout the water column in spring after oxygenation began, and much of this TP was removed from the euphotic zone through enhanced production (and sedimentation) of diatoms. Following oxygenation, epilimnetic [TP] was low at the beginning of the thermally stratified period, thus the potential maximum phytoplankton biovolume was reduced. (In Lake Ontario, extended spring mixing also led to a decrease in the amount of phosphorus available in summer; Lean 1987). In contrast, positive effects of hypolimnetic aeration may be masked or confounded in lakes with substantial external inputs of nutrients (Garrell et al. 1977; Bürgi and Stadelmann 1991). In lakes with moderate inorganic nitrogen concentrations (for example, 300 to 650 $\mu g \cdot L^{-1}$, indicating a mesotrophic lake; Wetzel 1983), a reduction of TP from the sediments may increase the relative amount of nitrogen available for plant growth, which may lead, in turn, to unacceptably high concentrations of green algae (Simm 1991). Results of the present study suggest that hypolimnetic oxygenation is a viable tool for altering phytoplankton community structure in favour of more diatoms and reduced cyanobacteria in thermally stratified, phosphorus-limited lakes with little or no external phosphorus input. Based on the four hypotheses that I set out

to test in this study, the following conclusions can be drawn: 1) hypolimnetic oxygenation resulted in a decrease in mean [Chl *a*] during the open water season; 2) hypolimnetic oxygenation did not result in lower [Chl *a*] in the treated basin than in the untreated basin; 3) Chl *a* was distributed deeper in the water column as a result of treatment; and 4) green algae did not increase in importance as a result of treatment, however, as a result of mixed conditions in the water column (enhanced by hypolimnetic oxygenation), the phytoplankton community was dominated by diatom species in spring, with dominance by cyanobacteria delayed until midway through the open-water season.

Treatment has continued in Amisk Lake, and mean summer epilimnetic [Chl *a*] in 1990 and 1991 (12.0 and 7.2 $\mu g \cdot L^{-1}$, respectively) has remained lower than historic values (t = 12.6 and 12.7, respectively; $P << 0.001$). Further studies are needed to answer the following:

1) Is oxygen injection immediately prior to and for a short period after ice-out sufficient to achieve deep-mixing in spring, or must injection be on a continual basis (as in this study)?

2) What is the minimum rate of oxygen injection necessary to accomplish deep-mixing in spring in deep, narrow lakes such as Amisk Lake?

3) Do diatoms continue to dominate the spring phytoplankton community after several years of hypolimnetic oxygenation in Amisk Lake?

4) Can deep-mixing in spring via hypolimnetic oxygenation/aeration enhance diatom blooms and delay cyanobacterial dominance in shallow lakes and/or in lakes in which external nutrient loading is significant?

Answers to these questions will further assist in the evaluation of the impact of oxygenation on sport fishery (through improved/increased food for zooplankton, and thus improved quality and quantity of food for planktivorous fish), and on water quality (greater clarity in the surface waters in summer due to less epilimnetic phytoplankton, and reduced development of cyanobacterial scums) in lakes.

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Table 4.1: Ranges of historical mean summer (June - August) data from Amisk Lake. Euphotic = 0-6 m; hypolimnetic = volume-weighted concentration below a depth of 8 m; epilimnetic = 3 m; Chl *a* = total chlorophyll *a*; TP = total phosphorus; Si = soluble reactive silica; TN:TP = mean ratio of total nitrogen to total phosphorus.

Parameter	Range
Euphotic Chl *a*[a]	9 - 25 $\mu g \cdot L^{-1}$
Euphotic TP[a]	26 - 40 $\mu g \cdot L^{-1}$
Hypolimnetic TP[b] (north basin)	100 - 155 $\mu g \cdot L^{-1}$
Hypolimnetic TP[c] (south basin)	116 - 148 $\mu g \cdot L^{-1}$
Epilimnetic Si[d]	2.7 $mg \cdot L^{-1}$
TN:TP[e]	21:1 - 36:1

[a]Prepas 1990; 1980-1987 (no data available for 1983)
[b]E. E. Prepas, unpubl.; 1980-1985 (excluding 1983)
[c]E. E. Prepas, unpubl.; 1980-1982
[d]T. P. Murphy, National Water Research Institute, Burlington, ON, unpubl.; 9 August 1987
[e]Prepas 1983; 1982

Table 4.2: Summary of coefficients of variation (%) in total chlorophyll *a* concentration between pairs of replicate samples. Data from 1988 and 1989 have been combined; data from all sites and all dates have been pooled. *n* = number of pairs of replicates; *SE* = standard error of the mean coefficient of variation.

Depth (m)	*n*	mean	*SE*	range
all	871	4.3	0.006	0 - 46
3	173	2.9	0.002	0 - 10
5.5	119	3.3	0.004	0 - 31
8	173	4.6	0.003	0 - 25
10.5	118	3.9	0.004	0 - 26
13	118	4.0	0.004	0 - 36
18	170	6.3	0.006	0 - 46

Table 4.3: Mean nutrient concentrations (±*SE*) in 1988 and 1989. TP = total phosphorus ($\mu g \cdot L^{-1}$); NO_3 = nitrite + nitrate ($\mu g \cdot L^{-1}$); NH_4 = ammonium ($\mu g \cdot L^{-1}$); TKN = total Kjeldahl nitrogen ($mg \cdot L^{-1}$); Si = soluble reactive silica ($mg \cdot L^{-1}$); spring mixed period = not applicable in 1988, 8 to 30 May 1989; thermally stratified period = 24 May to 20 September 1988, 6 June to 18 September 1989; fall mixed period = 20 October 1988, 2 to 16 October 1989; Hypolimnion = mid-hypolimnion. Blanks indicate no data.

Year/Period/ Stratum	TP		NO_3		NH_4		TKN		Si	
1988										
Thermally Stratified Period										
Epilimnion	30	(±1)	1	(±1)	7	(±2)	0.92	(±0.04)	1.45	(0.24)
Metalimnion	55	(±2)	26	(±8)	17	(±2)	0.82	(±0.03)	2.63	(±0.08)
Hypolimnion	102	(±5)	176	(±23)	92	(±11)	0.75	(±0.02)	4.58	(0.23)
Fall Mixed Period										
Epilimnion	44		9						3.40	
Metalimnion	42		12						3.40	
Hypolimnion	86		14						4.54	
1989										
Spring Mixed Period										
Epilimnion	57	(±3)	10	(±8)	8	(±5)	0.76	(±0.01)	1.85	(±0.13)
Metalimnion	58	(±1)	24	(±10)	14	(±4)	0.74	(±0.03)	2.74	(±0.56)
Hypolimnion	64	(±2)	98	(±9)	50	(±8)	0.72	(±0.05)	3.79	(±0.13)
Thermally Stratified Period										
Epilimnion	22	(±1)	1	(±1)	9	(±1)	0.90	(±0.05)	0.88	(±0.21)
Metalimnion	36	(±2)	23	(±5)	23	(±3)	0.78	(±0.02)	2.54	(±0.14)
Hypolimnion	82	(±5)	148	(±13)	64	(±5)	0.74	(±0.01)	4.49	(±0.06)
Fall Mixed Period										
Epilimnion	48	(±5)	32	(±8)	23	(±7)				
Metalimnion	48	(±5)	36	(±6)	26	(±7)				
Hypolimnion	82	(±16)	118	(±49)	57	(±6)				

Table 4.4: Summary of analyses of variance (three-factor ANOVA's: date x depth x site) of total chlorophyll *a* concentrations in 1988 and 1989. df = degrees of freedom; F = F-statistic; P = probability.

Year	Source	df	F	P
1988	date	8	3.62	< 0.001
	depth	2	118.04	$<< 0.001$
	site	5	0.54	> 0.5
	depth x site	10	0.09	> 0.9
	error	136		
1989	date	19	50.50	$<< 0.001$
	depth	5	108.82	$<< 0.001$
	site	5	1.67	> 0.1
	depth x site	25	0.30	> 0.9
	error	659		

Table 4.5: Summary of mean total chlorophyll *a* concentrations (Chl *a*; $\mu g \cdot L^{-1}$) over time. *n* = number of sampling dates included; *SE* = standard error of the mean; open-water season = all sampling dates; spring mixed period = not applicable in 1988, 8 to 30 May 1989; thermally stratified period = 24 May to 20 September 1988, 6 June to 18 September 1989; fall mixed period = 20 October 1988, 2 to 16 October 1989. Blanks indicate no data.

Time	Depth	1988 *n*	1988 Chl *a*	1988 *SE*	1989 *n*	1989 Chl *a*	1989 *SE*
Open-water	3	9	10.3	4.9	20	7.0	3.3
Season	5.5				20	7.5	2.6
	8	9	5.5	1.2	20	5.6	2.9
	10.5				20	4.2	2.7
	13				20	3.5	2.4
	18	9	1.8	1.2	20	2.5	1.9
Spring	3				4	9.7	4.0
Mixed	5.5				4	10.3	2.6
Period	8				4	9.7	2.2
	10.5				4	8.5	1.4
	13				4	7.5	1.1
	18				4	5.8	1.0
Thermally	3	8	11.2	4.9	14	6.1	3.0
Stratified	5.5				14	7.0	2.4
Period	8	8	5.4	1.4	14	4.3	2.0
	10.5				14	2.6	0.9
	13				14	2.0	0.8
	18	8	1.4	1.0	14	1.5	0.6
Fall	3	1	6.1	---	2	7.9	1.5
Mixed	5.5				2	7.4	1.2
Period	8	1	5.9	---	2	7.3	1.3
	10.5				2	6.9	0.8
	13				2	5.9	0.1
	18	1	3.5	---	2	3.3	2.0

Table 4.6: Summary of multiple comparisons (Student-Newman-Keuls tests) of mean total chlorophyll *a* concentrations (Chl *a*; $\mu g \cdot L^{-1}$) from all sampling depths among dates. Degrees of freedom = 136 and 659, n = 18 and 36 (1988 and 1989, respectively). Chl *a* = mean concentration from all depths. Dates with the same letter indicate concentrations that are not significantly different ($P < 0.05$).

Year	Date						Chl *a*
1988	2	August	A				8.6
	18	July	A	B			7.9
	15	August	A	B			7.2
	20	June		B			5.3
	24	May		B			5.2
	18	October		B			5.2
	4	July		B			5.2
	10	June		B			5.1
	20	September		B			4.8
1989	8	May	A				10.2
	17	May	A				9.7
	23	May		B			8.2
	2	October	C				6.9
	30	May	C	D			6.1
	16	October	C	D			6.0
	18	September	C	D			6.0
	6	June	E	D			5.0
	15	August	E	F			4.3
	9	August	E	F			4.2
	31	July	E	F	G		4.1
	22	August	E	F	G		4.0
	5	September	E	F	G	H	3.9
	25	July	E	F	G	H	3.8
	16	June	I	F	G	H	3.5
	18	July	I	F	G	H	3.3
	20	June	I	F	G	H	2.8
	11	July	I			H	2.7
	4	July	I			H	2.6
	28	June	I				2.4

Table 4.7: Phytoplankton taxa identified in Amisk Lake samples, 1988 and 1989.

Cyanobacteria

Anabaena flos-aquae
Aphanizomenon flos-aquae
Chroococcus sp.
Gloeocapsa sp.
Gomphosphaeria sp.
Lyngbya sp.
Oscillatoria sp.

Bacillariophyta

Asterionella formosa
Cyclotella spp.
Cymbella sp.
Fragilaria sp.
Navicula sp.
Stephanodiscus sp.
Synedra sp.

Chlorophyta

Ankistrodesmus sp.
Chlorella sp.
Cosmarium sp.
Crucigenia sp.
Elakatothrix sp.
Oocystis sp.
Quadrigula sp.
Staurastrum sp.
nannoflagellata

Cryptophyta

Cryptomonas sp.
Rhodomonas sp.

Table 4.8: Percentage composition of total phytoplankton biovolume (10^6 $\mu m^3 \cdot mL^{-1}$) by major phytoplankton groups and total chlorophyll *a* concentration ($\mu g \cdot L^{-1}$), 1988. Taxa listed below percentages contributed 20% or greater to total phytoplankton biovolume on those dates. *Aph=Aphanizomenon flos-aquae*; *Ast=Asterionella formosa*; *Ana=Anabaena flos-aquae*; *Lyn=Lyngbya* sp.; *Fra=Fragilaria* sp.

Group	24/05	10/06	20/06	04/07	18/07	02/08	15/08	20/09	18/10
Epilimnion									
Chlorophyll *a*	4.5	9.3	9.0	11.4	17.5	20.2	14.9	7.2	6.1
Total biovolume	1.0	2.8	3.5	2.4	6.9	8.0	1.3	0.4	0.3
Cyanobacteria	59	87	90	96	99	98	96	74	69
	Aph ---------->								
Bacillariophyta	25	10	5	1	0	0	0	4	5
	Ast								
Chlorophyta	3	1	1	2	1	1	2	11	11
Cryptophyta	14	2	3	2	0	1	2	11	15
Metalimnion									
Chlorophyll *a*	7.3	4.3	5.9	3.0	5.2	3.9	5.8	6.8	5.9
Total biovolume	0.6	1.0	0.6	0.4	1.1	1.0	0.4	0.4	0.3
Cyanobacteria	43	62	30	81	97	96	93	63	61
	Aph ---------->								
				Ana					*Lyn*
Bacillariophyta	41	34	57	1	1	0	0	5	8
	Ast ---------->		*Fra*						
Chlorophyta	5	2	4	13	1	2	5	22	22
Cryptophyta	11	2	9	5	1	2	2	10	9

Table 4.9: Percentage composition of total phytoplankton biovolume ($10^6 \mu m^3 \cdot mL^{-1}$) by major phytoplankton groups and total chlorophyll *a* concentrations ($\mu g \cdot L^{-1}$), 1989. Taxa listed below percentages contributed 20% or greater to total phytoplankton biovolume on those dates. *Ana=Anabaena flos-aquae*; *Aph=Aphanizomenon flos-aquae*; *Ast=Asterionella formosa*; *Cyc=Cyclotella* spp.; *Ooc=Oocystis* sp.; *Fra=Fragilaria* sp.; *Cry=Cryptomonas* sp.

Group	17/05	30/05	16/06	28/06	11/07	25/07	09/08	22/08	05/09	18/09	02/10	16/10
Epilimnion												
Chlorophyll *a*	9.5	6.2	3.8	3.6	3.8	5.6	7.7	8.0	8.8	11.0	9.0	6.3
Total biovolume	2.3	1.7	0.5	0.3	0.7	1.4	1.9	2.2	1.5	3.0	1.3	1.1
Cyanobacteria	5	6	56	60	85	95	93	98	96	97	94	62
			Ana		*Ana*	---------->						*Ana*
			Aph	---------->							*Aph*	------->
Bacillariophyta	92	85	16	4	6	1	0	0	1	0	1	32
	Ast	------->										*Fra*
	Cyc											
Chlorophyta	2	4	9	30	6	3	4	1	2	1	1	3
				Ooc								
Cryptophyta	1	5	19	7	3	1	2	0	2	2	3	3
Metalimnion												
Chlorophyll *a*	13.3	7.4	3.5	2.9	3.0	4.8	3.5	3.0	2.2	8.8	8.6	1.1
Total biovolume	2.4	1.5	0.3	0.1	0.2	0.4	0.3	.04	0.2	0.9	1.0	0.4
Cyanobacteria	0	5	31	20	68	89	70	93	89	92	88	89
			Aph		*Aph*	---------->						
					Ana		*Ana*	---------->				
Bacillariophyta	97	83	28	9	14	4	6	1	1	1	1	4
	Cyc	*Ast*										
Chlorophyta	1	3	9	51	15	5	22	6	6	3	7	4
				Ooc								
Cryptophyta	2	8	32	20	3	2	2	1	4	4	4	3
			Cry									

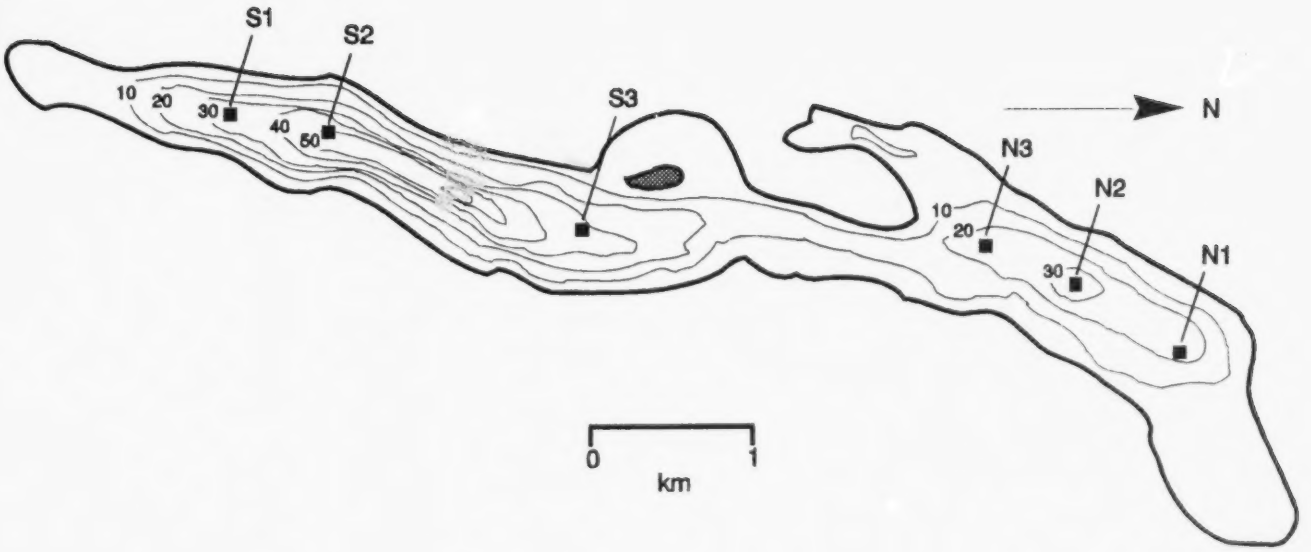

Fig. 4.1: Amisk Lake, Alberta. N1, N2, N3, S1, S2, and S3 = sampling sites.

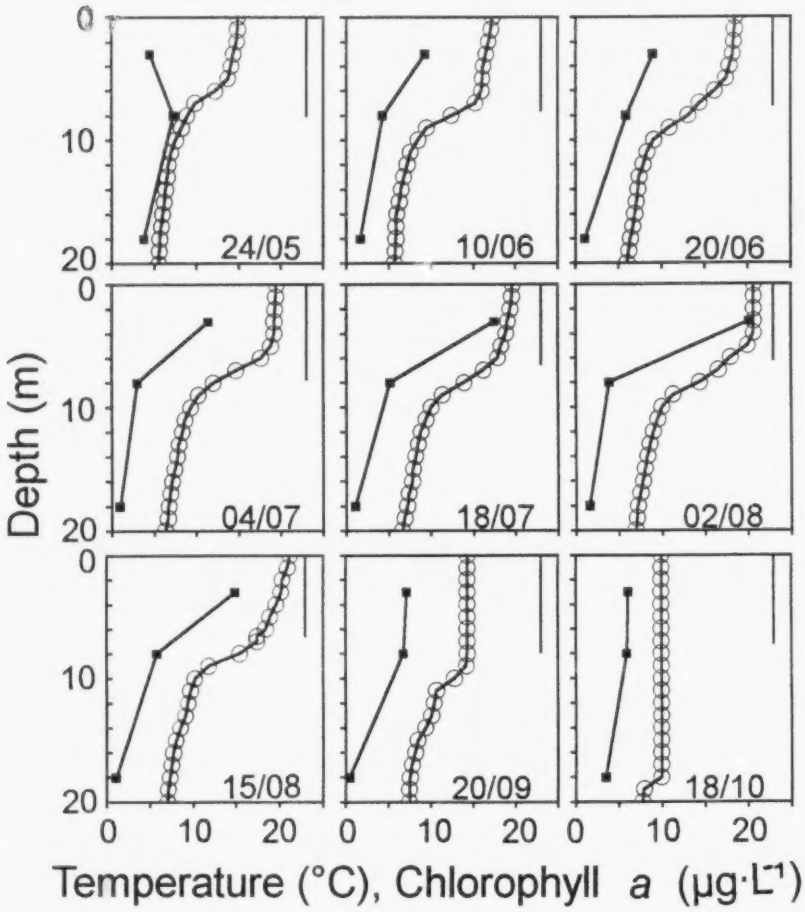

Figure 4.2: Vertical profiles of water temperature (○), total chlorophyll *a* concentration (■), and depth of euphotic zone (|) in Amisk Lake, Alberta, 1988.

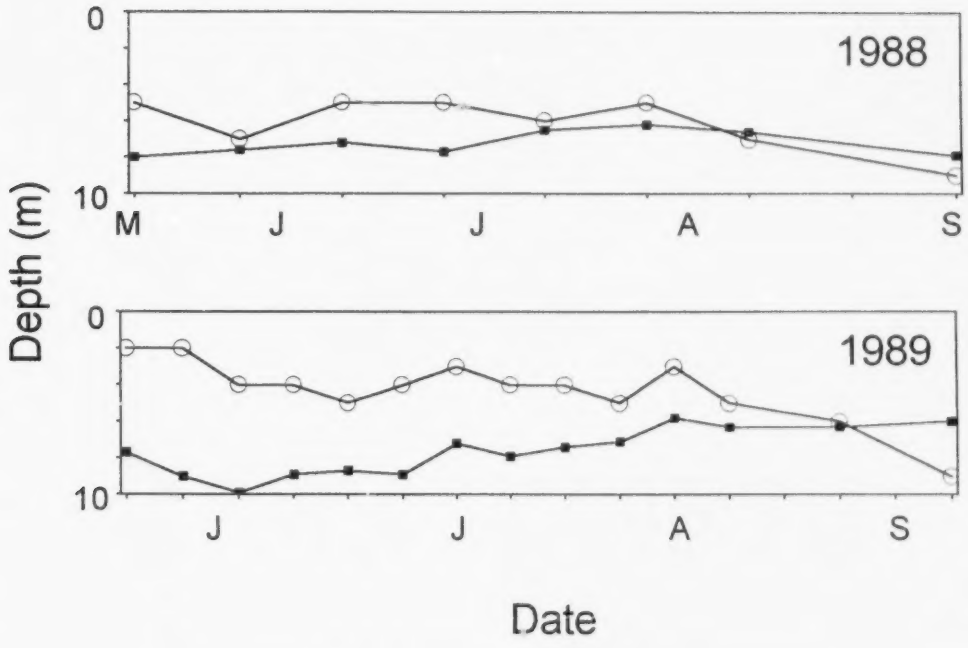

Figure 4.3: Depths of mixed layer (○) and euphotic zone (■) during the thermally stratified period in Amisk Lake, 1988 and 1989.

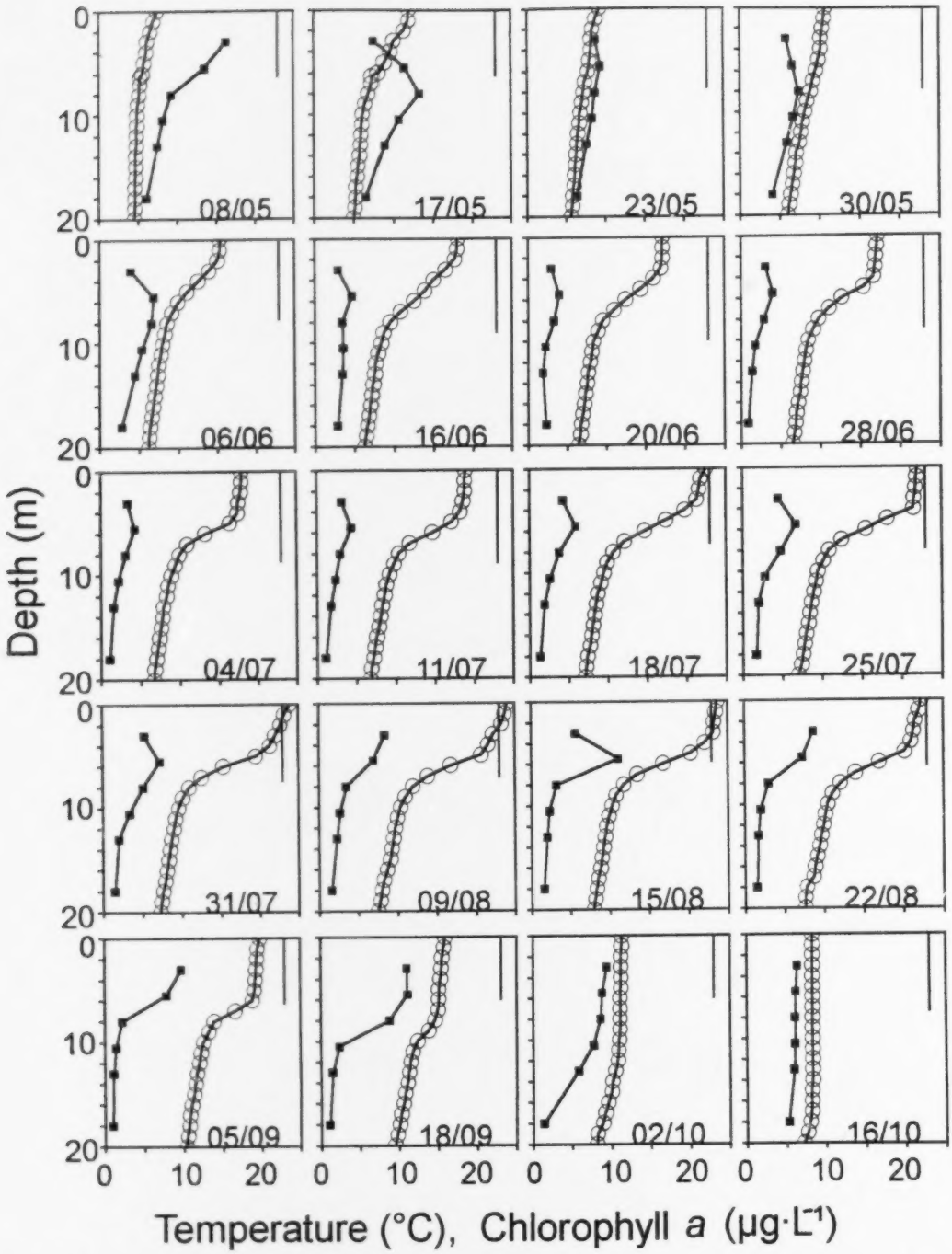

Figure 4.4: Vertical profiles of water temperature (○), total chlorophyll *a* concentration (■), and depth of euphotic zone (|) in Amisk Lake, Alberta, 1989.

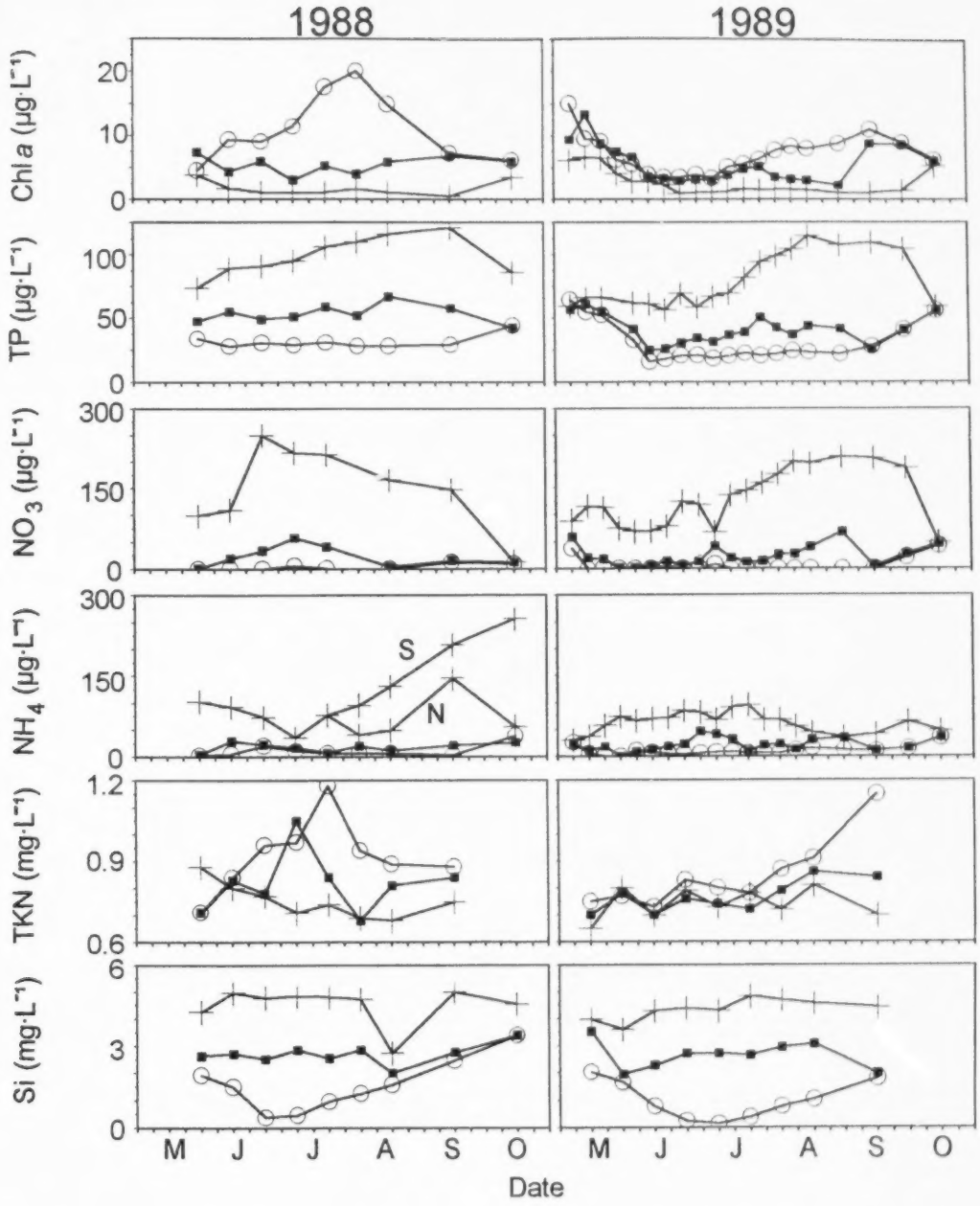

Figure 4.5: Nutrient concentrations in the epilimnion (○), metalimnion (■), and mid-hypolimnion (+) in Amisk Lake, Alberta in 1988 and 1989.Values are whole-lake mean concentrations, unless otherwise indicated. Chl *a* = total chlorophyll *a*; TP = total phosphorus; NO_3 = nitrite + nitrate; NH_4 = ammonium (N = north basin, S = south basin); TKN = total Kjeldahl nitrogen; Si = soluble reactive silica.

5. General Discussion

Phytoplankton are a major component in aquatic ecosystems, since they convert light energy to chemical energy that can be utilized by higher trophic levels. Because of the complex interactions among phytoplankton and the various other physical, chemical and biological components of a lake, any activity that impacts the phytoplankton community may result in significant changes throughout the entire aquatic ecosystem. Understanding the factors that control phytoplankton population size and species composition in a lake will enable lake managers to design appropriate treatment procedures and to predict the degree of success that can be expected from their efforts.

Measurement of Chlorophyll a Concentration

Measurement of [Chl *a*] is probably the most common method of monitoring basic changes in the phytoplankton community. Selection of a solvent suitable for the phytoplankton species present will improve the accuracy of [Chl *a*]. Historically, acetone has been the solvent of choice for Chl *a* extraction, especially in marine systems (Richards and Thompson 1952; Moss 1967; Strickland and Parsons 1972; Daemen 1986). However, freshwater systems are often dominated by cyanobacteria and/or green algae, from which extraction with acetone is poor; the extraction efficiencies of methanol, ethanol and various combinations of dimethyl sulfoxide and 90% acetone (DMSO/acetone) are generally superior to acetone for freshwater samples (Shoaf and Lium 1976; Holm-Hansen and Riemann 1978; Stauffer et al. 1979; Burnison 1980; Sartory and Grobbelaar 1984). Methanol and ethanol have similar extraction efficiencies from green algal cultures and from natural assemblages dominated by the cyanobacteria *Microcystis aeruginosa* (Sartory and Grobbelaar 1984; Jespersen and Christoffersen 1987), and 90% ethanol and DMSO/acetone have similar extraction efficiencies from a green algal culture (*Selenastrum capricornutum*; Sartory and Grobbelaar 1984). Prior to this study, comparisons of the extraction efficiencies of

ethanol and DMSO/acetone from natural assemblages of cyanobacteria and/or diatoms had not been published. Results from this study indicate that ethanol and DMSO/acetone are equally efficient at extracting Chl *a* from these samples. Because ethanol is less expensive and less offensive (in terms of odour) than DMSO/acetone, I recommend its use for routine determination of [Chl *a*] in all freshwater samples.

The technique used for determination of [Chl *a*] may depend on the specificity of results required in a given study. Results from this study support Neveux et al.'s (1990) conclusion that accurate [Pha] can only be derived through HPLC analysis, so for studies requiring reliable [Pha], spectrophotometry is not recommended. However, spectrophotometrically determined [Pha] may at least represent trends in degraded Chl *a*, and may be useful for indicating directly or indirectly the depth of the euphotic zone (Yentsch 1965), regions of high irradiance (Lorenzen 1967), regions of heavy zooplankton grazing (Glooschenko et al. 1972; Carpenter and Berquist 1985), collapse of a phytoplankton bloom (Nusch 1980), or a shift from dominance by diatoms and/or green algae to dominance by cyanobacteria (Gunnison and Alexander 1975). Spectrophotometrically determined [Chl *a*] (corrected for Pha) were not significantly different than corrected [Chl *a*] derived with HPLC analysis. Based on the results of this study, I recommend the use of spectrophotometry for measurement of [Chl *a*]: spectrophotometry is less expensive and the analytical equipment is usually more readily available than that for HPLC, and samples can be processed more rapidly and with relatively little technical skill compared to HPLC analysis. Although spectrophotometry appears to overestimate total [Chl *a*], this may not be of major importance for monitoring gross changes in primary productivity during lake rehabilitation studies. If pretreatment [Chl *a*] to which treatment data will be compared were not corrected for the presence of Pha, as was the case in this study, total [Chl *a*] is appropriate.

Impact of Hypolimnetic Oxygenation of the Phytoplankton Community

Hypolimnetic aeration has been reported to increase phytoplankton biomass, decrease phytoplankton biomass and/or alter the relative proportions of phytoplankton groups in treated lakes (LaBaugh 1980; Ashley 1982; Steinberg and Arzet 1984; McQueen and Story 1986; Bürgi and Stadelmann 1991; Ravera 1991; Simm 1991). This range of results is not encouraging if the objective of treatment was to reduce [Chl *a*]. In Amisk Lake, the primary objective of hypolimnetic oxygenation was to increase habitat for cold-water fish species; reduction of [Chl *a*] via reduced total phosphorus concentrations [TP] (through elimination of anoxia at the water-sediment interface in the hypolimnion) was a secondary objective. The second objective was, in fact, achieved: mean summer [TP] in the upper 6 m of the water column was lower in 1988 and 1989 (29 and 22 $\mu g \cdot L^{-1}$, respectively) than historical values (32 (± 2) $\mu g \cdot L^{-1}$), and [Chl *a*] in the same stratum were also significantly lower in 1988 and 1989 (10 and 8 $\mu g \cdot L^{-1}$, respectively) than historical [Chl *a*] (17 (± 2) $\mu g \cdot L^{-1}$) (E. E. Prepas, unpubl.).

Although hypolimnetic oxygenation did succeed in significantly reducing [TP], resulting in reduced [Chl *a*], perhaps a more important factor associated with the treatment was the impact of the extended period of deep-mixing in spring on the phytoplankton community. Oxygen was injected into the lake throughout the winter of 1988-1989. Because of the minimal temperature gradient between the top and bottom of the water column (from 0 to 3°C; E. E. Prepas, unpubl.), a relatively low rate of oxygen injection was probably sufficient to maintain circulation under the ice (Ashley 1988). When the ice went out, underwater currents resulting from oxygen injection insured deep-mixing of the water column, a condition which did not usually occur prior to treatment. As soon as the ice left the lake in 1989, the rate of injection was increased, thus delaying the development of thermal stratification. Turbulent conditions in the water column in spring 1989 promoted a massive growth of diatoms, a component of the phytoplankton community that was relatively unimportant in spring 1988. When thermal stratification was established in June 1989, the diatoms settled out

of the euphotic zone, removing a substantial quantity of nutrients bound up in cell components to the deeper portion of the water column. Thermal stratification effectively prevented transfer of nutrients back into the epilimnion, so maximum development of the cyanobacterial population was governed by the amount of TP that remained in the epilimnion after descent of the diatoms. As a result, maximum phytoplankton biovolume in 1989 was less than half of the 1988 maximum.

Control of phytoplankton was more successful in Amisk Lake than in many other studies involving hypolimnetic aeration for several reasons: 1) external TP inputs are minimal, so control of internal loading had a significant impact; 2) deep-mixing of the water column in spring 1989 was successfully induced and then maintained for about 4 wk, resulting in a large population of diatoms, which stripped a significant amount of nutrients from the epilimnion as the cells settled out the euphotic zone in June; and 3) thermal stratification was not disrupted during the summer months, so there was little or no transfer of nutrients from the hypolimnion to the epilimnion, thus limiting maximum development of the summer cyanobacterial community.

In summary, the following conclusions can be drawn based on the collective results of this study:

1) ethanol is a suitable solvent for Chl *a* analysis for freshwater samples, particularly those dominated by cyanobacteria;

2) spectrophotometric analysis is acceptable for determination of [Chl *a*] (corrected for Pha), and probably for determination of total [Chl *a*] in baseline monitoring studies;

3) spectrophotometrically determined [Pha] may represent trends in [Pha], but the accuracy of the concentrations is questionable; of the techniques currently available, HPLC is the most appropriate technique for obtaining accurate [Pha];

4) hypolimnetic oxygenation can successfully reduce [TP] in lakes in which external loading of TP is insignificant, thereby reducing [Chl *a*], providing TP is the main limiting factor in phytoplankton growth; and,

5) deep-mixing of the water column in spring is enhanced by hypolimnetic oxygenation, resulting in the growth of large diatom populations, which will

lead to a further reduction in [TP] in the epilimnion during thermal stratification, and thus a decrease in the maximum phytoplankton biovolume during the remainder of the thermally stratified period.

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Appendix

Data

Table 1: Temperature (℃), 1988. Depth = m. Blanks indicate no data.

Site	Depth	24/05	10/06	20/06	04/07	18/07	02/08	15/08	20/09	18/10
N2	0	14.9	17.2	18.5	19.4	19.4	20.5	20.8	14.1	10.0
	1	14.8	16.9	18.4	19.4	19.3	20.6	20.4	14.1	10.0
	2	14.7	16.3	18.2	19.3	19.0	20.6	20.1	14.1	10.0
	3	14.5	16.1	18.2	19.3	18.8	20.6	20.0	14.1	10.0
	4	14.0	16.1	18.1	19.2	18.7	20.5	19.5	14.1	10.0
	5	13.7	16.0	17.4	18.5	18.2	19.2	18.8	14.1	10.0
	6	11.1	15.9	15.5	16.8	17.8	17.4	18.5	14.1	10.0
	7	9.4	15.3	12.5	15.0	16.2	16.2	17.7	14.1	10.0
	8	8.5	12.2	11.8	12.3	14.3	13.6	15.0	14.1	10.0
	9	8.2	9.4	9.7	10.0	11.5	10.8	12.1	14.1	10.0
	10	7.8	8.5	8.9	8.9	10.0	10.0	10.0	12.4	10.0
	11	7.2	7.4	8.3	8.5	9.2	9.6	9.6	10.0	10.0
	12	6.8	7.1	8.1	8.2	8.7	9.2	9.4	10.0	10.0
	13	6.7	6.9	7.4	7.9	8.6	9.1	9.3	10.0	10.0
	14	6.4	6.7	7.4	7.8	8.5	8.9	9.1	9.9	10.0
	15	6.2	6.7	7.3	7.7	8.3	8.7	9.1	9.7	10.0
	16	6.2	6.7	7.2	7.5	8.3	8.6	8.9	9.6	10.0
	17	6.1	6.7	7.1	7.5	8.1	8.5	8.8	9.5	10.0
	18	6.1	6.7	7.0	7.5	8.0	8.4	8.8	9.5	10.0
	19	6.1	6.7	6.9	7.5	8.0	8.4	8.7	9.5	10.0
	20	6.0	6.6	6.9	7.4	7.9	8.3	8.7	9.5	10.0
	21	5.9	6.5	6.9	7.3	7.9	8.3	8.6	9.5	9.5
	22	5.8	6.5	6.9	7.3	7.9	8.2	8.6	9.4	9.5
	23	5.8	6.4	6.8	7.3	7.8	8.2	8.6	9.4	9.5
	24	5.8	6.4	6.8	7.2	7.8	8.2	8.6	9.4	9.5
	25	5.8	6.4	6.8	7.2	7.8	8.2	8.5	9.4	9.5
	26	5.8	6.4	6.8	7.2	7.8	8.2	8.5	9.4	9.5
	27	5.8	6.3	6.8	7.2	7.8	8.2	8.5	9.4	9.5
	28	5.8	6.3	6.7	7.2	7.8	8.2	8.5	9.4	9.5
	29	5.8	6.3	6.7	7.2	7.8	8.1	8.5	9.4	9.0
	30	5.8	6.3	6.7	7.1	7.8	8.1	8.5	9.4	9.0

Table 1 continued

Site	Depth	24/05	10/06	20/06	04/07	18/07	02/08	15/08	20/09	18/10
S1	0	15.0	17.3	18.6	19.6	20.0	20.8	21.6	14.5	9.8
	1	15.0	17.2	18.6	19.4	19.9	20.8	21.3	14.5	9.8
	2	14.9	17.2	18.6	19.2	19.7	20.8	20.5	14.5	9.8
	3	14.3	16.8	18.3	19.1	19.3	20.8	20.4	14.5	9.8
	4	14.3	16.3	17.6	19.1	19.1	20.8	19.6	14.5	9.8
	5	13.8	16.2	17.5	19.0	18.3	20.8	19.0	14.5	9.8
	6	13.4	16.1	16.9	18.3	17.9	18.5	18.2	14.5	9.8
	7	10.3	15.1	16.3	14.4	16.2	17.0	17.0	14.5	9.8
	8	9.3	12.5	14.3	11.6	13.5	15.2	13.9	14.5	9.8
	9	8.3	9.5	12.1	10.3	11.1	11.7	11.5	14.2	9.8
	10	7.3	8.4	9.2	9.6	10.0	10.0	10.3	13.2	9.8
	11	6.8	7.7	8.2	8.6	9.5	9.3	9.8	11.3	9.8
	12	6.5	7.2	7.7	8.3	8.8	8.8	9.4	10.8	9.8
	13	6.4	6.6	7.4	7.8	8.3	8.0	8.8	10.2	9.8
	14	6.3	6.2	7.1	7.5	7.9	7.7	7.8	8.8	9.8
	15	6.2	5.8	6.8	7.1	7.5	7.2	6.9	7.3	9.8
	16	5.8	5.3	6.6	6.7	7.3	6.9	6.4	6.8	9.8
	17	5.6	5.0	6.3	6.3	6.7	6.5	6.1	6.1	9.8
	18	5.2	5.0	5.8	5.9	6.3	6.0	5.7	5.7	9.8
	19	5.1	4.9	5.4	5.6	5.8	5.7	5.5	5.5	5.7
	20	5.0	4.8	5.1	5.2	5.3	5.4	5.3	5.4	5.4
	21	5.0	4.8	5.0	5.0	5.0	5.0	5.2	5.3	5.2
	22	5.0	4.7	4.9	5.0	5.0	5.0	5.0	5.1	5.0
	23	4.9	4.6	5.8	4.9	5.0	5.0	5.0	5.0	5.0
	24	4.7	4.5	4.7	4.8	4.8	4.9	4.9	5.0	5.0
	25	4.6	4.4	4.6	4.8	4.7	4.9	4.8	4.9	4.9
	26	4.5	4.4	4.6	4.8	4.6	4.9	4.8	4.8	4.8
	27	4.4	4.3	4.6	4.7	4.6	4.9	4.8	4.7	4.8
	28	4.3	4.3	4.5	4.6	4.6	4.9	4.7	4.7	4.7
	29	4.3	4.3	4.4	4.6	4.5	4.9	4.7	4.7	4.6
	30	4.3	4.3	4.4	4.5		4.9		4.7	4.6

Table 2: Temperature (°C), 1989. Depth = m. Blanks indicate no data.

Site	Depth	08/05	17/05	23/05	30/05	06/06	16/06	20/06	28/06	04/07	11/07
N1	0	7.3	11.8	8.3	10.9	15.9	18.7	16.8	17.2	17.9	18.6
	1	7.2	11.8	7.9	10.8	15.9	18.6	16.8	17.2	17.9	18.6
	2	7.0	11.7	7.5	10.7	15.1	17.6	16.8	16.8	17.8	18.4
	3	6.7	8.8	7.3	10.7	12.2	15.7	16.8	16.7	17.7	18.1
	4	6.3	7.8	7.3	10.7	11.3	14.2	16.8	16.5	17.6	18.0
	5	6.1	7.2	7.2	9.8	10.0	13.7	16.8	16.1	16.8	17.3
	6	5.9	7.0	7.2	9.2	9.6	11.7	13.6	12.5	12.9	12.9
	7	5.8	6.8	7.2	8.3	9.4	10.4	11.8	11.4	10.8	11.5
	8	5.7	6.7	7.1	8.0	9.1	9.1	9.3	9.9	9.9	10.4
	9	5.6	6.4	7.0	7.6	8.9	8.3	8.6	9.0	9.1	9.9
	10	5.5	6.3	6.7	7.4	8.8	8.1	8.2	8.5	8.9	9.4
	11	5.5	6.2	6.6	7.1	8.3	8.0	7.9	8.3	8.6	9.2
	12	5.3	6.1	6.5	7.0	8.0	7.8	7.8	8.1	8.4	8.9
	13	5.2	6.0	6.4	6.9	7.9	7.6	7.6	7.9	8.1	8.5
	14	5.1	5.9	6.3	6.8	7.7	7.5	7.5	7.7	8.0	8.3
	15	5.0	5.7	6.2	6.7	7.4	7.4	7.3	7.7	7.9	8.2
	16	5.0	5.7	6.2	6.6	7.2	7.2	7.2	7.6	7.8	8.1
	17	4.9	5.6	6.2	6.5	7.0	7.1	7.2	7.4	7.7	8.0
	18	4.9	5.5	6.1	6.4	6.9	7.0	7.2	7.4	7.7	7.8
	19	4.9	5.5	6.1	6.3	6.8	6.9	7.1	7.3	7.5	7.7
	20	4.8	5.4	6.0	6.2	6.6			7.2	7.4	7.6

Table 2 continued

Site	Depth	18/07	25/07	31/07	09/08	15/08	22/08	05/09	18/09	02/10	16/10
N1	0	23.1	21.5	23.7		24.1	22.1	20.5	15.6	11.3	8.3
	1	22.2	21.1	23.0		24.1	21.9	20.3	15.4	11.3	8.3
	2	21.8	21.0	22.6		23.8	21.7	19.9	15.3	11.2	8.3
	3	21.5	20.9	22.2		23.6	21.6	19.9	15.2	11.2	8.3
	4	20.1	20.8	21.6		22.1	21.4	19.8	15.1	11.1	8.3
	5	17.7	19.3	20.0		20.8	19.6	19.8	14.9	11.1	8.3
	6	15.7	15.5	15.5		16.4	16.7	19.6	14.8	11.1	8.3
	7	12.0	12.8	12.7		13.6	14.5	17.0	14.8	11.1	8.3
	8	11.0	10.7	11.2		12.0	12.5	14.7	14.7	11.1	8.3
	9	10.0	9.9	10.1		11.1	11.6	14.1	14.7	11.1	8.3
	10	9.2	9.4	9.6		10.6	10.6	13.1	12.5	11.1	8.3
	11	9.0	9.1	9.3		10.3	10.3	12.8	12.0	11.1	8.3
	12	8.6	8.9	9.0		9.8	10.1	12.7	11.9	11.0	8.3
	13	8.4	8.6	8.8		9.6	9.9	12.6	11.5	11.0	8.3
	14	8.3	8.5	8.7		9.5	9.8	12.5	11.3	11.0	8.3
	15	8.2	8.4	8.6		9.4	9.7	12.5	11.2	10.9	8.3
	16	8.1	8.3	8.6		9.2	9.6	12.4	11.1	10.7	8.2
	17	8.1	8.3	8.5		9.2	9.6	12.3	11.0	10.1	8.2
	18	8.0	8.2	8.5		9.1	9.6	12.3	11.0	9.9	8.2
	19	7.9	8.1	8.4		9.1	9.6	12.2	10.8	9.8	8.2
	20	7.9	8.1	8.3		9.0	9.5	12.2	10.8	9.8	8.1

Table 2 continued

Site	Depth	08/05	17/05	23/05	30/05	06/06	16/06	20/06	28/06	04/07	11/07
N2	0	7.0	12.5	8.9	10.5	15.7	18.6	16.8	16.9	17.9	18.7
	1	6.8	12.5	8.0	10.5	15.7	18.5	16.8	16.7	17.8	18.6
	2	6.8	10.3	7.5	10.4	15.4	17.8	16.8	16.6	17.8	18.6
	3	6.7	8.7	7.4	10.3	13.3	15.4	16.8	16.6	17.5	18.3
	4	6.6	8.3	7.4	10.3	10.0	14.5	16.8	16.5	17.5	17.7
	5	5.7	7.2	7.4	10.2	9.6	14.0	16.0	15.5	15.4	16.8
	6	5.4	6.9	7.3	9.6	9.1	12.7	13.5	13.5	11.5	13.9
	7	5.3	6.8	7.2	8.9	8.7	10.9	11.7	11.7	10.2	11.2
	8	5.2	6.7	7.1	8.6	8.5	9.7	10.5	10.0	10.0	9.9
	9	5.0	6.4	7.0	8.2	8.3	8.9	9.3	9.1	9.5	9.5
	10	5.0	6.3	6.8	7.8	8.1	8.4	8.4	8.4	9.3	8.8
	11	5.0	6.1	6.7	7.6	7.9	8.0	8.1	8.3	8.8	8.7
	12	5.0	5.9	6.5	7.4	7.8	7.6	7.9	8.1	8.6	8.7
	13	5.0	5.8	6.4	7.0	7.6	7.5	7.8	8.0	8.4	8.5
	14	5.0	5.8	6.4	6.9	7.5	7.5	7.7	7.7	8.3	8.2
	15	5.0	5.7	6.1	6.8	7.1	7.3	7.6	7.7	8.0	8.1
	16	5.0	5.7	6.1	6.7	6.8	7.2	7.5	7.6	7.9	8.0
	17	5.0	5.6	6.1	6.7	6.7	7.1	7.4	7.4	7.8	7.9
	18	4.9	5.5	6.0	6.6	6.6	7.0	7.4	7.4	7.6	7.8
	19	4.9	5.5	5.9	6.4	6.6	7.0	7.3	7.3	7.5	7.8
	20	4.9	5.5	5.9	6.4	6.6	7.0	7.2	7.2	7.5	7.7
	21	4.9	5.5	5.9	6.4	6.5	7.0	7.2	7.2	7.4	7.7
	22	4.9	5.4	5.9	6.3	6.5	6.9	7.1	7.2	7.3	7.6
	23	4.9	5.4	5.8	6.3	6.5	6.9	7.0	7.2	7.3	7.6
	24	4.8	5.4	5.8	6.3	6.5	6.9	7.0	7.2	7.3	7.5
	25	4.8	5.4	5.8	6.3	6.4	6.8	7.0	7.1	7.3	7.5
	26	4.8	5.4	5.7	6.3	6.4	6.8	6.9	7.1	7.3	7.5
	27	4.7	5.3	5.7	6.3	6.3	6.8	6.9	7.0	7.2	7.5
	28	4.7	5.3	5.7	6.2	6.3	6.8	6.9	7.0	7.2	7.5
	29	4.7	5.3	5.6	6.2	6.3	6.7	6.9	7.0	7.2	7.5
	30	4.7	5.3	5.6	6.2		6.7	6.9	7.0	7.2	7.5

Table 2 continued

Site	Depth	18/07	25/07	31/07	09/08	15/08	22/08	05/09	18/09	02/10	16/10
N2	0	23.0	21.9	24.0	24.6	23.7	21.8	20.5	16.0	11.3	8.3
	1	22.0	21.9	23.2	24.2	23.6	21.5	20.3	15.9	11.3	8.3
	2	21.7	21.6	22.7	23.5	23.5	21.3	19.9	15.6	11.3	8.3
	3	21.2	21.3	22.0	22.5	23.3	20.9	19.7	15.5	11.3	8.3
	4	20.0	21.0	21.5	21.5	21.1	20.8	19.7	15.3	11.3	8.3
	5	17.7	18.0	19.8	20.3	19.1	20.1	19.6	15.2	11.3	8.3
	6	15.0	15.6	15.4	16.2	15.5	16.2	19.4	15.2	11.2	8.3
	7	11.6	12.1	12.5	13.6	13.0	13.9	17.9	14.9	11.2	8.3
	8	10.2	10.2	11.0	11.5	11.4	11.5	14.3	14.6	11.2	8.3
	9	9.5	9.8	10.1	10.7	10.5	10.9	13.5	14.1	11.2	8.3
	10	9.4	9.3	9.4	10.2	10.1	10.1	13.2	12.7	11.1	8.3
	11	9.0	9.1	9.1	9.9	9.8	9.9	12.8	11.9	11.1	8.3
	12	8.7	9.0	9.0	9.8	9.6	9.8	12.6	11.7	11.1	8.3
	13	8.6	8.8	8.8	9.6	9.2	9.6	12.5	11.6	11.0	8.3
	14	8.5	8.6	8.7	9.5	9.1	9.5	12.5	11.4	10.5	8.3
	15	8.4	8.5	8.7	9.4	9.1	9.4	12.4	11.4	10.4	8.3
	16	8.3	8.5	8.6	9.4	9.0	9.4	12.3	11.3	10.3	8.3
	17	8.2	8.4	8.5	9.2	9.0	9.4	12.2	11.2	10.2	8.3
	18	8.1	8.3	8.5	9.2	8.9	9.3	12.2	11.2	10.0	8.3
	19	8.1	8.3	8.5	9.0	8.8	9.3	12.1	11.1	9.9	8.2
	20	8.0	8.2	8.4	9.0	8.8	9.3	12.0	11.0	9.8	8.2
	21	8.0	8.1	8.3	9.0	8.8	9.3	12.0	11.0	9.7	8.2
	22	8.0	8.1	8.3	8.9	8.8	9.2	12.0	10.9	9.7	8.2
	23	7.9	8.1	8.3	8.8	8.7	9.2	11.9	10.9	9.7	8.2
	24	7.9	8.0	8.3	8.8	8.7	9.1	11.9	10.8	9.7	8.1
	25	7.9	8.0	8.2	8.8	8.6	9.1	11.9	10.8	9.6	8.1
	26	7.9	8.0	8.2	8.8	8.6	9.1	11.8	10.7	9.6	8.1
	27	7.8	8.0	8.1	8.8	8.6	9.1	11.8	10.7	9.6	8.1
	28	7.8	8.0	8.1	8.8	8.6	9.1	11.8	10.7	9.6	8.1
	29	7.8	8.0	8.1	8.8	8.6	9.0	11.7	10.7	9.6	8.1
	30	7.8	7.9	8.1	8.8	8.5	9.0	11.6	10.7	9.6	8.1

Table 2 continued

Site	Depth	08/05	17/05	23/05	30/05	06/06	16/06	20/06	28/06	04/07	11/07
N3	0	6.7	12.5	8.6	10.6	15.5	18.5	16.5	17.2	17.7	18.8
	1	6.5	12.5	8.2	10.6	15.5	18.5	16.6	17.1	17.7	18.8
	2	6.4	11.3	7.8	10.5	15.1	18.1	16.6	17.0	17.6	18.5
	3	6.1	8.4	7.6	10.5	14.8	16.8	16.6	16.7	17.4	18.4
	4	5.9	8.0	7.5	10.4	12.8	14.9	15.5	16.4	17.3	18.1
	5	5.9	7.4	7.4	10.3	10.8	12.8	13.6	15.3	16.5	16.3
	6	5.9	7.0	7.1	10.2	8.6	12.2	13.0	13.1	13.1	14.6
	7	5.5	6.1	6.9	9.8	8.0	10.4	12.1	11.8	9.5	12.8
	8	5.2	5.8	6.8	9.0	7.7	9.7	10.9	9.9	9.1	10.5
	9	5.0	5.8	6.6	7.5	7.2	9.4	9.9	9.4	9.0	9.8
	10	5.0	5.6	6.5	7.0	7.1	8.5	9.1	8.6	8.4	9.3
	11	5.0	5.6	6.4	6.7	7.1	8.0	8.6	8.1	8.3	8.8
	12	4.9	5.5	6.3	6.6	7.0	7.6	8.2	7.8	8.1	8.5
	13	4.9	5.5	6.2	6.5	6.9	7.5	8.1	7.6	7.9	8.3
	14	4.9	5.5	6.1	6.5	6.6	7.4	7.9	7.6	7.7	8.3
	15	4.9	5.4	6.1	6.4	6.5	7.2	7.6	7.5	7.7	8.2
	16	4.8	5.4	6.0	6.3	6.5	7.1	7.5	7.4	7.6	8.1
	17	4.8	5.4	5.9	6.3	6.5	7.0	7.4	7.4	7.5	8.0
	18	4.8	5.4	5.9	6.3	6.5	7.0	7.2	7.3	7.5	7.9
	19	4.8	5.4	5.9	6.2	6.5	6.9	7.2	7.2	7.5	7.7
	20	4.8		5.7	6.2	6.5	6.9	7.0	7.2	7.4	7.7

Table 2 continued

Site	Depth	18/07	25/07	31/07	09/08	15/08	22/08	05/09	18/09	02/10	16/10
N3	0	23.3	21.1	24.4		23.8	22.4	19.8	16.4	11.8	8.3
	1	22.3	21.1	23.8		23.6	22.3	19.6	16.1	11.8	8.3
	2	22.1	21.1	22.7		23.4	21.7	19.5	15.9	11.7	8.3
	3	21.6	21.1	22.1		23.3	21.4	19.4	15.8	11.6	8.3
	4	19.7	20.9	21.5		22.1	21.1	19.2	15.7	11.6	8.3
	5	17.8	18.4	20.0		19.5	20.5	19.1	15.6	11.6	8.2
	6	15.0	15.4	14.8		15.4	17.2	19.1	15.6	11.5	8.2
	7	11.7	12.8	11.9		12.8	13.1	17.9	15.5	11.5	8.2
	8	10.8	10.8	10.7		11.5	11.7	14.4	14.1	11.4	8.2
	9	10.1	9.9	10.1		10.5	10.6	13.8	13.3	11.4	8.2
	10	9.9	9.6	9.7		9.9	10.3	12.9	12.9	11.0	8.2
	11	9.4	9.3	9.3		9.5	10.2	12.6	12.6	10.6	8.2
	12	8.9	9.0	9.0		9.2	9.9	12.5	12.1	10.5	8.2
	13	8.6	8.8	8.9		9.1	9.7	12.4	12.0	10.5	8.2
	14	8.5	8.7	8.7		9.0	9.6	12.3	11.9	10.4	8.2
	15	8.4	8.7	8.6		9.0	9.6	12.2	11.6	10.3	8.2
	16	8.3	8.6	8.5		9.0	9.5	12.2	11.5	10.2	8.2
	17	8.1	8.5	8.5		8.9	9.5	12.1	11.4	10.2	8.2
	18	8.0	8.3	8.3		8.9	9.4	12.1	11.4	10.2	8.1
	19	8.0	8.1	8.3		8.8	9.4	12.1	11.3	9.9	8.1
	20	7.9		8.2		8.7		12.1	11.2	9.8	7.9

Table 2 continued

Site	Depth	08/05	17/05	23/05	30/05	06/06	16/06	20/06	28/06	04/07	11/07
S1	0	8.1	12.1	10.0	10.1	15.3	17.7	17.8	17.4	18.0	19.1
	1	6.8	12.0	9.6	10.0	15.2	17.5	17.9	17.3	17.9	19.1
	2	6.4	11.9	9.2	10.0	15.1	17.5	17.9	17.2	17.7	19.2
	3	6.0	11.8	9.1	10.0	14.7	17.5	16.7	17.1	17.1	19.2
	4	5.8	11.6	9.0	10.0	13.9	16.1	14.3	16.7	16.8	18.5
	5	5.7	10.6	8.5	10.0	12.0	14.3	12.7	14.4	16.1	17.8
	6	5.0	8.6	7.8	10.0	10.2	12.5	12.0	12.1	14.2	16.6
	7	4.5	8.0	7.4	10.0	9.1	11.9	10.8	10.5	11.0	12.0
	8	4.5	6.8	7.1	9.9	8.3	9.5	9.6	9.6	9.9	10.6
	9	4.4	6.5	6.9	9.8	8.0	8.2	9.1	9.0	9.2	9.8
	10	4.4	6.4	6.8	9.6	7.8	8.3	8.5	8.5	8.8	9.4
	11	4.3	6.2	6.6	9.0	7.5	7.9	8.1	8.3	8.5	8.8
	12	4.3	6.1	6.5	8.7	7.3	7.7	8.0	8.0	8.2	8.5
	13	4.3	5.9	6.4	8.2	7.3	7.5	7.7	7.7	7.9	8.2
	14	4.3	5.7	6.3	7.3	7.1	7.2	7.6	7.4	7.6	8.2
	15	4.3	5.5	6.3	7.2	7.0	7.1	7.4	7.2	7.4	7.7
	16	4.2	5.3	6.1	6.8	6.9	7.0	7.1	6.9	7.0	7.3
	17	4.2	5.2	5.9	6.7	6.6	6.8	6.9	6.6	6.8	7.0
	18	4.2	5.2	5.7	6.6	6.3	6.3	6.5	6.2	6.6	6.6
	19	4.2	5.1	5.6	6.3	6.0	6.1	6.4	6.1	6.2	6.1
	20	4.2	4.8	5.5	5.9	5.8	5.8	6.0	5.9	6.0	5.7
	21	4.1	4.8	5.4	5.7	5.5	5.6	5.6	5.6	5.8	5.5
	22	4.0	4.7	5.0	5.5	5.3	5.5	5.4	5.4	5.5	5.3
	23	4.0	4.6	5.0	5.2	5.1	5.3	5.3	5.3	5.4	5.2
	24	4.0	4.6	4.8	5.0	5.1	5.2	5.2	5.2	5.3	5.1
	25	3.9	4.6	4.6	5.0	5.0	5.1	5.1	5.0	5.2	5.1
	26	3.9	4.6	4.5	4.9	5.0	5.0	5.0	5.0	5.0	5.1
	27	3.8	4.5	4.4	4.8	5.0	5.0	5.0	5.0	5.0	5.0
	28	3.8	4.5	4.3	4.8	5.0	4.9	5.0	4.9	5.0	4.7
	29		4.5	4.3	4.7	4.9	4.9	5.0	4.9	5.0	4.7
	30			4.3	4.7	4.9	4.9	5.0	4.8	5.0	4.6

Table 2 continued

Site	Depth	18/07	25/07	31/07	09/08	15/08	22/08	05/09	18/09	02/10	16/10
S1	0	22.3	22.8	23.1	23.3	23.1	22.6	19.1	15.9	10.9	8.2
	1	21.6	22.6	23.0	23.0	23.1	22.1	18.6	15.6	10.9	8.2
	2	21.4	22.5	22.4	22.5	22.9	21.6	18.6	15.5	11.0	8.2
	3	20.7	22.4	21.6	21.9	22.8	21.1	18.5	15.4	11.0	8.2
	4	19.0	22.3	21.2	21.6	22.6	20.8	18.4	15.4	11.0	8.2
	5	17.3	17.5	19.1	20.8	21.0	20.1	18.4	15.3	11.0	8.2
	6	15.0	16.4	15.3	16.8	17.4	17.3	17.5	15.3	11.0	8.2
	7	13.1	12.2	12.7	14.5	13.4	14.1	15.8	15.2	11.0	8.2
	8	10.6	11.2	11.2	12.5	12.1	12.8	12.8	15.2	11.0	8.2
	9	9.9	10.4	10.0	11.2	11.0	11.4	12.2	12.6	11.0	8.2
	10	9.4	9.7	9.6	10.5	10.6	10.7	11.6	12.1	11.0	8.2
	11	8.9	9.4	9.2	10.1	10.3	10.3	11.2	11.6	10.9	8.2
	12	8.7	9.1	9.0	9.8	9.8	10.1	10.9	11.4	10.5	8.2
	13	8.4	8.8	8.5	9.6	9.7	9.7	10.5	11.2	9.7	8.2
	14	8.0	8.3	8.2	9.3	9.4	9.5	9.9	10.8	9.1	8.2
	15	7.8	7.9	7.8	8.8	9.2	9.0	9.6	10.4	8.6	8.2
	16	7.6	7.4	7.5	8.4	8.9	8.5	9.4	9.7	8.4	8.2
	17	7.1	7.1	7.1	7.9	8.2	8.0	9.2	9.4	7.7	8.2
	18	6.8	6.9	6.7	7.6	7.7	7.6	9.1	9.1	7.0	8.1
	19	6.5	6.7	6.4	7.3	7.3	7.1	8.5	9.1	6.2	7.4
	20	6.2	6.5	6.1	7.1	7.0	6.9	8.3	8.2	6.0	6.2
	21	5.8	6.3	5.9	6.7	6.8	6.5	8.2	7.9	5.8	6.0
	22	5.6	6.2	5.7	6.5	6.6	6.4	7.9	7.8	5.6	5.7
	23	5.4	6.0	5.5	6.4	6.4	6.3	7.8	7.6	5.5	5.6
	24	5.3	5.7	5.4	6.3	6.2	6.2	7.6	7.5	5.5	5.5
	25	5.2	5.6	5.3	6.2	6.1	6.2	7.5	7.4	5.4	5.4
	26	5.2	5.5	5.1	6.1	6.1	6.2	7.3	7.3	5.3	5.2
	27	5.1	5.4	5.0	6.0	6.0	5.9	7.2	7.2	5.3	5.2
	28	5.0	5.3	5.0	5.9	6.0	5.9	7.1	7.1	5.3	5.1
	29	5.0	5.2	5.0	5.8	5.9	5.8	7.1	7.1	5.2	5.0
	30	5.0		5.0	5.8	5.8	5.7	7.0	7.0	5.2	

Table 2 continued

Site	Depth	08/05	17/05	23/05	30/05	06/06	16/06	20/06	28/06	04/07	11/07
S2	0	8.1	11.4	10.1	10.5	15.1	17.7	17.7	17.5	18.0	19.1
	1	7.3	11.4	10.0	10.4	15.1	17.6	17.7	17.3	17.9	19.1
	2	6.2	11.3	9.4	10.2	15.1	17.5	17.7	17.2	17.9	19.1
	3	5.8	11.0	9.2	10.0	14.2	17.0	17.7	17.1	17.2	19.0
	4	5.6	10.9	9.1	10.0	13.1	15.1	15.1	17.0	17.0	18.8
	5	5.5	10.5	9.1	9.7	12.2	14.2	12.8	14.5	16.5	17.7
	6	5.2	9.3	8.8	9.5	10.6	13.3	11.2	12.1	14.0	16.1
	7	5.1	7.9	7.5	9.4	9.3	10.7	10.0	10.5	12.3	12.3
	8	4.6	7.4	7.2	9.2	8.9	9.5	9.0	9.6	10.5	10.6
	9	4.5	7.2	6.9	8.9	8.1	8.9	8.8	9.2	9.7	10.1
	10	4.4	6.5	6.9	8.6	7.7	8.6	8.3	8.7	9.0	9.3
	11	4.4	6.4	6.6	8.4	7.4	8.1	8.2	8.4	8.5	8.8
	12	4.4	6.2	6.6	8.4	7.1	7.9	7.9	8.1	8.1	8.4
	13	4.3	6.1	6.4	8.2	7.0	7.7	7.6	7.9	8.0	8.2
	14	4.3	5.9	6.2	8.0	6.9	7.5	7.5	7.6	7.7	7.8
	15	4.3	5.5	6.0	7.6	6.7	7.2	7.3	7.3	7.5	7.6
	16	4.3	5.2	5.9	7.3	6.5	6.9	7.1	7.0	7.2	7.3
	17	4.2	5.0	5.8	6.6	6.2	6.5	6.9	6.8	6.7	7.0
	18	4.2	5.0	5.7	6.2	6.1	6.2	6.5	6.6	6.4	6.7
	19	4.1	4.9	5.5	6.0	5.7	6.1	6.5	6.2	6.1	6.1
	20	4.1	4.9	5.4	5.8	5.6	5.8	6.1	5.9	5.9	5.9
	21	4.1	4.8	5.4	5.6	5.4	5.4	5.9	5.6	5.8	5.6
	22	4.0	4.7	5.3	5.5	5.1	5.3	5.7	5.4	5.7	5.5
	23	4.0	4.6	5.2	5.4	5.0	5.2	5.5	5.4	5.6	5.3
	24	3.9	4.5	5.0	5.3	5.0	5.1	5.4	5.2	5.3	5.2
	25	3.9	4.5	5.0	5.2	5.0	5.1	5.3	5.1	5.2	5.1
	26	3.8	4.5	4.9	5.0	5.0	5.0	5.2	5.0	5.1	5.1
	27	3.7	4.4	4.8	5.0	5.0	5.0	5.1	5.0	5.1	5.1
	28	3.7	4.4	4.6	4.9	5.0	5.0	5.1	5.0	5.0	5.1
	29	3.6	4.4	4.5	4.8	5.0	5.0	5.0	5.0	5.0	5.1
	30	3.6	4.4	4.5	4.8	4.9	5.0	5.0	5.0	5.0	5.1
	35	3.4	4.2	4.3	4.5	4.7	4.8		4.8	5.0	4.7
	40	3.3			4.5				4.8	4.9	4.6
	45	3.3			4.4				4.7	4.9	

Table 2 continued

Site	Depth	18/07	25/07	31/07	09/08	15/08	22/08	05/09	18/09	02/10	16/10
S2	0	21.7	23.2	23.9	24.4	23.7	23.1	19.2	15.5	11.1	8.3
	1	21.5	22.9	23.2	24.2	23.4	22.7	19.1	15.2	11.1	8.3
	2	21.3	22.5	23.0	24.1	23.3	21.9	19.0	15.1	11.1	8.3
	3	21.2	22.3	21.8	22.3	23.1	21.8	18.9	15.1	11.1	8.3
	4	19.2	22.2	20.7	21.6	22.5	21.2	18.8	14.9	11.0	8.3
	5	16.2	18.0	19.1	21.0	21.0	20.5	18.8	14.6	11.0	8.3
	6	13.6	15.9	15.7	16.9	17.7	17.3	18.3	14.5	11.0	8.3
	7	12.4	13.1	12.9	14.1	14.1	14.6	14.8	14.5	11.0	8.3
	8	11.0	11.7	11.0	12.1	11.4	12.3	13.3	14.2	11.0	8.3
	9	10.1	10.7	10.1	11.0	10.7	11.3	12.4	13.7	11.0	8.3
	10	9.5	9.8	9.7	10.5	10.3	10.9	12.0	11.1	11.0	8.3
	11	9.2	9.5	9.3	10.1	10.0	10.4	11.7	10.7	11.0	8.3
	12	8.7	9.2	9.0	9.7	9.6	10.1	11.3	10.5	11.0	8.3
	13	8.4	8.8	8.7	9.5	9.5	9.6	11.0	10.3	9.9	8.3
	14	8.1	8.4	8.3	9.3	9.2	9.0	10.7	10.1	8.9	8.3
	15	7.8	8.1	8.0	9.1	9.1	8.4	10.3	9.9	8.9	8.3
	16	7.5	7.7	7.6	8.5	8.5	7.9	9.7	9.8	8.7	8.2
	17	7.2	7.3	7.3	8.0	8.1	7.6	9.3	9.7	8.6	8.0
	18	6.6	6.7	7.0	7.5	7.7	7.3	9.1	9.1	8.4	7.8
	19	6.4	6.4	6.5	7.3	7.4	6.9	8.7	8.0	6.5	7.3
	20	6.1	6.1	6.0	6.9	7.1	6.8	8.2	7.7	6.2	6.8
	21	5.9	5.8	5.7	6.7	6.9	6.6	7.9	7.3	5.9	6.1
	22	5.6	5.7	5.5	6.5	6.6	6.4	7.7	7.2	5.7	5.8
	23	5.5	5.6	5.4	6.4	6.4	6.3	7.6	6.9	5.6	5.6
	24	5.3	5.6	5.2	6.3	6.2	6.2	7.5	6.8	5.5	5.4
	25	5.2	5.5	5.2	6.2	6.1	6.1	7.5	6.6	5.4	5.3
	26	5.1	5.4	5.1	6.1	6.0	6.0	7.4	6.6	5.4	5.3
	27	5.1	5.3	5.1	6.1	6.0	6.0	7.3	6.5	5.3	5.2
	28	5.1	5.3	5.0	6.0	5.9	5.9	7.3	6.5	5.3	5.1
	29	5.0	5.2	5.0	5.9	5.8	5.8	7.3	6.5	5.3	5.0
	30	5.0	5.1	5.0	5.8	5.8	5.8	7.2	6.4	5.3	5.0
	35	5.0	5.0	5.0	5.6	5.6	5.7	7.0	6.3	5.2	5.0
	40	4.9	4.8	5.0	5.5	5.5	5.6	6.9	6.2	5.1	5.0
	45	4.9	4.7	4.9	5.5	5.4	5.5	6.8		4.9	4.9

Table 2 continued

Site	Depth	08/05	17/05	23/05	30/05	06/06	16/06	20/06	28/06	04/07	11/07
S3	0	7.9	11.3	10.0	11.7	15.1	17.5	17.5	17.2	18.0	18.8
	1	7.5	11.3	9.1	11.1	15.0	17.4	17.5	17.1	18.0	18.8
	2	6.7	11.2	8.9	10.8	15.0	17.4	17.5	17.0	18.0	18.8
	3	6.1	11.2	8.8	9.8	14.7	16.4	17.5	17.0	18.0	18.7
	4	6.1	10.7	8.7	9.5	14.5	15.0	17.5	16.9	17.9	18.3
	5	5.9	10.2	8.6	9.4	12.6	14.1	14.4	16.8	17.0	16.6
	6	5.9	9.6	8.3	9.2	11.8	12.5	11.7	12.6	13.4	14.0
	7	5.8	8.2	8.2	9.0	10.6	10.7	9.5	10.9	11.5	11.1
	8	5.8	7.8	7.9	8.8	9.2	9.6	8.4	9.8	10.2	10.3
	9	5.7	6.9	7.5	8.7	9.1	8.7	8.2	8.9	9.9	9.6
	10	5.1	6.3	7.2	8.5	8.7	8.4	8.1	8.3	8.8	8.9
	11	5.0	6.1	7.0	8.3	8.3	8.1	8.0	8.0	8.4	8.7
	12	4.8	6.0	6.7	8.2	7.9	7.6	7.9	7.9	8.3	8.4
	13	4.8	5.9	6.5	7.9	7.6	7.5	7.5	7.8	8.2	8.2
	14	4.8	5.8	6.3	7.3	7.3	7.3	7.4	7.5	7.3	7.8
	15	4.7	5.7	6.2	7.0	7.1	7.1	7.1	7.3	7.3	7.4
	16	4.7	5.4	6.0	6.8	6.6	6.9	6.6	6.9	6.9	7.0
	17	4.6	5.1	5.8	6.6	6.4	6.6	6.4	6.6	6.7	6.6
	18	4.6	5.0	5.6	6.2	6.2	6.4	6.2	6.4	6.3	6.4
	19	4.4	4.7	5.5	6.0	6.1	6.2	5.9	6.1	6.1	6.1
	20	4.2	4.5	5.3	5.7	6.0	6.1	5.7	5.8	5.9	6.1
	21	4.1	4.5	5.1	5.5	6.0	6.0	5.7	5.7	5.8	5.8
	22	4.0	4.4	5.0	5.5	5.8	5.6	5.4	5.5	5.6	5.4
	23	4.0	4.4	4.8	5.3	5.6	5.4	5.4	5.4	5.4	5.3
	24	4.0	4.2	4.7	5.1	5.5	5.2	5.3	5.4	5.1	5.2
	25	4.0	4.1	4.6	4.9	5.3	5.0	5.3	5.2	5.0	5.2
	26	4.0	4.1	4.5	4.8	5.2	5.0	5.2	5.1	5.0	5.2
	27		4.0	4.4	4.7	5.1	5.0	5.1	5.0	5.0	5.1
	28			4.3	4.7	5.0	4.9	5.0	5.0	5.0	5.0
	29			4.3	4.7	5.0	4.8	5.0	5.0	4.9	4.9
	30			4.3	4.6	5.0	4.8	4.9	4.9	4.9	4.8

Table 2 continued

Site	Depth	18/07	25/07	31/07	09/08	15/08	22/08	05/09	18/09	02/10	16/10
S3	0	21.5	21.7	24.0	23.8	23.8	21.8	19.4	15.9	11.1	8.3
	1	21.4	21.9	23.0	23.4	23.3	21.3	19.3	15.7	11.1	8.3
	2	21.3	21.9	22.7	22.9	23.0	21.0	19.2	15.5	11.1	8.3
	3	21.3	21.8	22.5	22.2	22.9	20.9	19.1	15.3	11.1	8.3
	4	20.5	21.8	21.2	21.7	21.9	20.8	19.1	15.2	11.1	8.3
	5	17.4	18.0	19.0	20.8	20.2	20.2	18.9	15.1	11.1	8.3
	6	14.1	14.1	15.0	17.3	18.1	17.1	18.8	15.1	11.0	8.3
	7	11.8	11.9	12.2	13.5	14.1	13.6	15.9	14.9	11.0	8.3
	8	10.4	10.8	10.3	11.8	12.3	11.9	14.1	14.9	11.0	8.3
	9	9.9	10.2	9.9	10.9	10.8	10.8	13.1	14.4	11.0	8.3
	10	9.4	9.3	9.3	10.2	10.1	10.3	12.4	13.1	11.0	8.3
	11	9.1	9.1	9.1	9.7	9.7	9.9	12.1	11.8	10.9	8.3
	12	8.7	8.7	8.9	9.5	9.5	9.8	11.8	11.5	10.9	8.3
	13	8.5	8.6	8.7	9.2	9.1	9.8	11.4	11.2	10.9	8.3
	14	8.3	8.5	8.4	9.1	9.1	9.3	11.1	10.8	10.9	8.3
	15	8.0	8.0	8.1	8.9	8.4	8.9	10.5	10.3	10.8	8.1
	16	7.8	7.6	7.7	8.5	8.1	8.4	10.0	9.9	9.3	8.1
	17	7.2	7.2	7.2	8.1	7.7	8.1	9.7	8.9	8.5	8.1
	18	6.7	7.0	6.8	7.8	7.5	7.8	9.4	8.7	8.0	7.7
	19	6.4	6.8	6.4	7.5	7.2	7.5	9.1	8.3	7.1	7.1
	20	6.2	6.3	6.0	7.0	6.9	7.2	8.7	8.2	6.9	6.2
	21	6.0	6.0	5.8	6.6	6.5	7.1	8.4	7.9	6.7	5.9
	22	5.7	5.9	5.6	6.5	6.3	6.8	8.3	7.6	6.4	5.7
	23	5.5	5.6	5.5	6.3	6.1	6.5	8.2	7.6	6.0	5.5
	24	5.4	5.6	5.3	6.2	6.1	6.4	8.1	7.5	5.9	5.4
	25	5.3	5.5	5.2	6.1	5.8	6.1	7.9	7.4	5.7	5.3
	26	5.3	5.4	5.2	6.1	5.7	6.0	7.8	7.4	5.7	5.3
	27	5.2	5.4	5.1	6.0	5.7	6.0	7.7	7.4	5.7	5.1
	28	5.1	5.4	5.0	6.0	5.7	5.9	7.7	7.2	5.5	5.0
	29	5.0	5.0								
	30	5.0									

Table 3: Underwater light extinction, 1988. Data are given as a percentage of the photosynthetically active radiation measured at 0.2 m. Si = site; Dep = depth (m). Blanks indicate no data.

Si	Dep	24/05	10/06	20/06	04/07	18/07	02/08	15/08	20/09	18/10
N2	0.2	100.0	100.0	100.0					100.0	100.0
	1	50.0	62.3	52.4					57.0	47.1
	2	33.3	30.2	21.4					29.0	18.8
	3	17.6	12.8	11.4					14.0	10.6
	4	10.5	7.4	6.2					7.9	4.4
	5	6.0	4.2	3.0					4.5	2.6
	6	3.3	2.5	1.6					2.8	1.4
	7	1.6	1.1	0.9					1.5	0.8
	8	0.9	0.7	0.6					0.9	0.4
	9	0.5	0.4	0.3						0.2
	10	0.3	0.2	0.2						0.1
S1	0.2	100.0	100.0	100.0					100.0	100.0
	1	36.3	57.6	58.3					43.8	37.5
	2	21.9	27.1	17.5					31.3	
	3	13.1	10.5	11.7					13.8	10.8
	4	8.8	6.1	7.1					7.5	5.6
	5	4.4	3.6	4.6					4.2	3.6
	6	2.8	1.9	1.4					2.5	2.2
	7	1.7	1.0	0.9					1.5	1.3
	8	1.0	0.6	0.6					0.9	0.7
	9	0.5	0.4	0.2					0.6	0.5
	10	0.3	0.3	0.1					0.3	0.3

Table 4: Underwater light extinction, 1989. Data are given as a percentage of the photosynthetically active radiation measured at 0.2 m. Si = site; Dep = depth (m); PR = data collected with Protomatic light meter; LC = data collected with Li-Cor light meter. Blanks indicate no data.

Si	Dep	08/05 LC	17/05 PR	17/05 LC	23/05 PR	23/05 LC	30/05 PR	30/05 LC	06/06 PR	06/06 LC
N1	0.2	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
	1	39.2	43.9	45.8	51.2	52.4	30.6	60.7	22.5	40.0
	2	14.6	18.8	16.8	25.6	28.6	26.7	30.0	15.0	20.0
	3	4.8	8.3	6.3	10.5	26.2	15.6	16.7	10.0	10.0
	4	2.1	3.4	2.4	5.8	23.8	9.7	9.3	6.0	7.0
	5	0.9	1.4	1.1	3.3	14.3	5.6	6.2	3.5	4.0
	6	0.4	0.5	0.5	1.7	10.5	2.8	3.4	2.5	2.0
	7	0.2	0.3	0.2	1.0	6.2	1.8	1.9	1.3	1.3
	8	0.1	0.0	0.1	0.6	3.3	1.0	0.9	0.7	0.8
	9	0.1		0.1	0.3	2.9	0.5	0.5	0.4	0.5
	10	0.0		0.1	0.2	1.9	0.3	0.3	0.2	0.3
N2	0.2	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
	1	44.4	62.3	53.8	55.6	52.9	61.2	55.6	50.0	53.8
	2	13.6	52.8	38.5	28.9	20.6	28.6	33.3	28.3	26.9
	3	5.6	41.5		15.6	11.2	14.5	16.7	11.7	15.4
	4	2.2	24.5	19.2	7.1	5.9	9.6	5.6	5.0	3.5
	5	1.0	11.3	8.8	3.3	2.9	5.1	5.0	3.7	2.9
	6	0.5	5.7	3.8	2.2	1.2	3.3	2.9	2.5	1.9
	7	0.2	2.6	1.5	1.3	0.4	1.7	1.7	1.5	1.2
	8	0.1	1.3	1.2	0.6	0.3	1.0	1.1	0.8	0.7
	9	0.1	0.7	0.6	0.4	0.2	0.6	0.6	0.5	0.4
	10	0.0	0.4	0.3	0.2	0.1	0.4	0.2	0.3	0.2

Table 4 continued

Si	Dep	16/06 PR	16/06 LC	20/06 PR	28/06 LC	04/07 LC	11/07 LC	18/07 LC	25/07 LC	31/07 LC
N1	0.2	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
	1	65.0	56.7	65.8	57.1	52.6	73.3	66.7	60.0	55.6
	2	13.5	32.2	39.5	32.1	31.6	40.0	12.7	40.0	33.3
	3	18.0	21.1	28.9	19.3	15.8	26.7	6.7	20.0	16.7
	4	12.0	13.3	7.9	10.7	9.2	18.0	3.3	13.3	9.2
	5	7.5	7.9	6.6	6.0	5.3	10.7	1.7	2.0	4.7
	6	4.1	4.3	5.0	3.9	3.2	5.9	0.9	1.7	2.3
	7	2.6	2.7	3.4	2.4	1.8	3.4	0.5	0.7	1.3
	8	1.6	1.2	1.4	1.5	1.1	1.9	0.3	0.5	0.7
	9	1.1		1.1	1.0	0.7	1.1	0.2	0.4	0.4
	10	0.7		0.8	0.6	0.5	0.3	0.2	0.3	0.3
N2	0.2	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
	1	60.0	62.4	65.8	55.8	73.3	45.5	60.0	62.5	58.8
	2	40.0	40.0	42.1	33.5	46.7	34.1	45.0	34.4	27.1
	3	25.2	24.7	31.6	20.5	20.0	22.7	36.0	20.0	16.2
	4	14.8	15.3	10.5	13.0	13.3	13.6	25.0	11.9	8.8
	5	8.4	8.1	7.4	5.6	7.3	7.3	16.0	7.5	4.4
	6	6.0	4.9	5.3	4.5	5.3	5.7	11.0	3.4	2.2
	7	3.1	3.1	3.9	2.7	2.7	4.5	7.5	1.7	1.2
	8	2.0	1.8	1.4	1.6	1.7	4.1	5.4	1.1	0.6
	9	1.2	1.1	1.1	1.0	1.0	3.4	3.9	0.8	0.4
	10	0.7	0.8	0.7	0.7	0.7	2.7	3.0	0.6	0.2

Table 4 continued

Si	Dep	09/08 PR	15/08 PR	22/08 PR	05/09 PR	18/09 PR	02/10 PR	16/10 PR
N1	0.2	100.0	100.0	100.0	100.0	100.0	100.0	100.0
	1	55.6	50.0	54.2	49.1	53.6		35.7
	2	33.3	25.0	25.4	16.9	30.4	13.8	16.8
	3	11.1	14.8	13.4	7.8	17.9	6.7	12.7
	4	6.0	6.3	6.1	3.5	10.9	4.5	7.9
	5	3.8	2.0	2.9	1.6	6.3	2.4	5.2
	6	1.2	1.0	1.4	0.8	3.4	1.2	3.0
	7	0.7	0.5	0.8	0.5	2.0	0.6	1.8
	8	0.4	0.3	0.4	0.3	1.0	0.3	1.0
	9	0.3	0.1	0.2	0.0	0.6	0.2	0.6
	10	0.1	0.1	0.1	0.0	0.3	0.1	0.4
N2	0.2	100.0	100.0	100.0	100.0	100.0	100.0	100.0
	1	59.0	52.6	30.6	38.3	45.2		45.8
	2	28.2	23.7	12.2	16.5	24.5	18.5	23.3
	3	14.9	11.6	5.1	8.0	12.9	10.0	15.0
	4	5.9	5.3	2.7	4.2	6.5	5.5	8.8
	5	3.1	2.6	1.4	2.0	2.8	2.5	5.4
	6	1.5	1.1	0.4	1.1	1.5	1.3	2.9
	7	0.7	0.5	0.2	0.6	0.7	0.8	1.6
	8	0.4	0.2	0.1	0.4	0.4	0.4	0.9
	9	0.2	0.1	0.1	0.2	0.3	0.2	0.5
	10	0.1	0.0	0.0	0.0	0.1	0.1	0.3

Table 4 continued

Si	Dep	08/05 LC	17/05 PR	17/05 LC	23/05 PR	23/05 LC	30/05 PR	30/05 LC	06/06 PR	06/06 LC
N3	0.2	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
	1	38.8	42.3	26.7	50.0	38.9	59.5	58.8	53.3	46.7
	2	14.0	19.6	16.7	27.5	22.2	23.8	35.3	26.7	12.0
	3	6.0	9.6	10.0	12.5	17.8	16.7	20.0	13.3	6.7
	4	2.8	5.0	3.3	6.3	14.4	9.5	11.8	7.3	3.3
	5	1.3	2.1	1.3	2.5	7.8	5.5	5.9	4.3	3.0
	6	0.6	1.0	0.7	1.0	4.4	3.3	4.7	2.4	1.7
	7	0.3	0.5	0.3	0.5	3.3	1.9	3.2	1.3	0.9
	8	0.2	0.2	0.2	0.3	1.8	1.0	1.9	0.8	0.5
	9	0.1	0.1	0.1	0.1	1.0	0.6	1.5	0.5	0.3
	10	0.1	0.0	0.1	0.0	0.8	0.4	0.9	0.2	0.2
S1	0.2	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
	1.0	53.3	49.0	28.2	66.7	70.0	57.1	48.0	36.1	47.7
	2.0	30.6	17.0	11.3	33.3	30.0	27.9	32.0	22.2	23.1
	3.0	25.0	8.1	6.9	18.7	15.0	16.4	14.4	16.7	15.4
	4.0	17.2	4.2	3.8	10.0	7.0	9.3	6.8	11.1	8.5
	5.0	13.9	2.1	2.1	5.3	3.8	4.3	5.0	6.9	5.4
	6.0	7.8	1.0	1.0	3.2	2.0	2.8	3.8	3.0	2.9
	7.0	4.4	0.6	0.4	2.0	1.1	1.6	2.1	1.8	1.7
	8.0	2.5	0.2	0.2	1.1	0.7	0.9	1.3	1.1	1.4
	9.0	1.4	0.1	0.1	0.6	0.4	0.5	0.7	0.8	1.1
	10.0	0.8		0.1	0.4	0.2	0.3	0.4	0.4	0.5

Table 4 continued

Si	Dep	16/06 PR	16/06 LC	20/06 PR	28/06 LC	04/07 LC	11/07 LC	18/07 LC	25/07 *	31/07 LC
N3	0.2	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
	1	64.6	66.0	60.0	68.0	66.7	50.0	54.5	65.2	58.8
	2	40.8	40.0	42.0	34.0	33.3	27.5	36.4	32.2	29.4
	3	24.6	25.0	32.0	18.0	13.3	17.5	11.4	17.4	14.7
	4	16.2	15.6		10.0	9.3	11.3	6.8	8.7	7.6
	5	10.0	9.4	6.0	5.4	5.0	7.5	4.5	5.2	4.6
	6	5.9	5.6	4.4	3.3	3.3	4.5	2.5	2.8	2.3
	7	3.7	3.4	3.0	2.1	2.0	2.5	1.4	1.4	1.5
	8	2.2	2.0	1.0	1.3	1.2	1.5	0.8	0.6	0.5
	9	1.4	1.3	0.7	0.9	0.7	0.9	0.2	0.4	0.3
	10	0.8	0.8	0.5	0.6	0.5	0.6	0.1	0.3	0.2
S1	0.2	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
	1	65.4	55.7	41.7	57.9	60.0	8.0	60.0	56.1	60.0
	2	36.9	34.3	25.0	35.8	32.0	4.4	12.8	34.1	30.0
	3	21.9	22.9	20.8	24.2	18.0	3.2	7.2	17.3	13.3
	4	15.4	14.3	15.0	13.2	10.8	2.8	3.6	9.8	6.7
	5	9.6	9.3	10.0	6.8	6.4	2.8	2.0	5.1	3.6
	6	6.2	5.4	5.4	3.4	4.0	2.2	1.2	2.7	1.7
	7	3.5	3.1	4.2	1.7	2.4	1.2	0.8	1.5	0.9
	8	2.4	2.0	2.3	0.9	1.4	0.8	0.5	0.9	0.5
	9	1.3	1.2	1.3	0.4	1.0	0.5	0.4	0.5	0.4
	10	0.9	0.6	0.8	0.2	0.6	0.3	0.3	0.3	0.3

* N3 = LC; S1 = PR

Table 4 continued

Si	Dep	09/08 PR	15/08 PR	22/08 PR	05/09 PR	18/09 PR	02/10 PR	16/10 PR
N3	0.2	100.0	100.0	100.0	100.0	100.0	100.0	100.0
	1	57.7	59.1	50.0	41.4	31.7		41.7
	2	26.9	31.8	25.0	15.7	12.2	14.7	20.0
	3	13.5	15.9	11.3	6.7	5.4	6.5	12.5
	4	4.8	7.5	6.3	3.2	2.1	2.9	6.7
	5	2.3	2.5	2.5	1.6	1.0	1.3	3.6
	6	1.2	0.9	1.1	0.8	0.5	0.7	1.9
	7	0.7	0.4	0.8	0.4	0.2	0.3	0.6
	8	0.2	0.2	0.4	0.2	0.1	0.2	0.3
	9	0.1	0.0	0.1	0.1	0.0	0.1	0.1
	10	0.1	0.0	0.0	0.0	0.0	0.0	0.0
S1	0.2	100.0	100.0	100.0	100.0	100.0	100.0	100.0
	1	47.6	38.0	50.0	44.3	33.6		64.3
	2	23.5	8.0	20.6	39.2	12.7	20.0	29.3
	3	10.6	4.0	7.8	8.4	5.1	8.2	12.1
	4	4.0	2.6	4.3	4.3	2.2	3.7	6.4
	5	2.1	1.0	1.9	2.3	1.1	1.7	3.4
	6	1.3	0.4	1.0	1.3	0.5	0.8	1.9
	7	0.9	0.1	0.6	0.7	0.2	0.4	1.1
	8	0.6	0.1	0.3	0.5	0.1	0.2	0.5
	9	0.5		0.2	0.3		0.1	0.3
	10	0.4			0.2			0.2

Table 4 continued

Si	Dep	08/05 LC	17/05 PR	17/05 LC	23/05 PR	23/05 LC	30/05 PR	30/05 LC	06/06 PR	06/06 LC
S2	0.2	100.0	100.0	100.0		100.0	100.0	100.0	100.0	100.0
	1	67.4	37.8	45.5		66.7	21.6	53.3	56.0	45.0
	2	24.8	18.4	21.2		33.3	19.5	28.0	35.0	10.0
	3	11.3	10.2	13.6		15.0	11.6	15.3	20.0	7.5
	4	6.3	5.6	6.1		10.0	7.6	7.3	14.0	5.0
	5	3.0	2.6	2.9		5.0	4.6	3.7	7.5	3.3
	6	1.7	1.4	1.4		2.8	2.7	2.3	4.3	2.0
	7	1.0	0.6	1.2		1.7	1.4	1.3	3.0	1.5
	8	0.6	0.3	0.3		1.0	0.8	0.7	1.5	1.0
	9	0.3	0.1	0.2		0.5	0.5	0.4	0.9	0.7
	10	0.2	0.1	0.1		0.3	0.2	0.1	0.6	0.3
S3	0.2	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
	1	64.2	40.7	45.6	62.5	50.0	68.0	57.9	46.7	52.0
	2	24.2	16.5	18.8	32.5	15.0	32.0	26.3	23.3	30.0
	3	10.0	8.2	8.7	15.0	7.0	12.4	12.6	11.3	13.0
	4	3.2	3.8	4.4	8.5	4.5	6.8	7.3	8.7	8.0
	5	1.5	1.8	2.1	4.5	2.5	3.6	3.8	4.3	4.8
	6	0.8	0.8	0.9	2.3	1.5	2.0	2.0	2.7	2.8
	7	0.5	0.4	0.4	1.5	1.0	1.1	1.2	1.7	1.5
	8	0.2	0.2	0.2	0.9	0.5	0.6	0.7	1.0	0.9
	9	0.1		0.1	0.5	0.2	0.4	0.3	0.5	0.5
	10	0.1		0.1	0.3	0.1	0.2	0.2	0.3	0.3

Table 4 continued

Si	Dep	16/06 PR	16/06 LC	20/06 PR	28/06 LC	04/07 LC	11/07 LC	18/07 LC	25/07 PR	31/07 LC
S2	0.2	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
	1	55.7	66.7	62.5	63.6	60.0	28.2	43.5	61.5	55.6
	2	37.1	30.0	45.0	34.5	32.0	23.1	9.8	35.9	24.4
	3	22.1	19.2	32.5	19.5	8.0	15.4	5.4	19.5	6.7
	4	15.7	11.7	25.0	12.3	6.0	10.3	3.3	12.3	3.0
	5	12.9	6.3	15.0	6.8	4.8	6.4	1.6	6.9	2.0
	6	5.6	4.0	10.0	4.3	4.0	3.8	0.9	3.6	1.3
	7	3.4	2.4	6.8	2.8	2.2	2.6	0.5	1.8	0.7
	8	2.2	1.5	4.4	1.8	1.6	1.3	0.3	1.0	0.5
	9	1.5	0.9	2.9	1.2	1.0		0.2	0.5	0.3
	10	0.9	0.2	1.8	0.8	0.6		0.2	0.3	0.2
S3	0.2	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
	1	83.3	47.1	66.7	63.2	53.8	62.5	20.0	68.4	65.0
	2	27.8	32.4	43.3	38.9	30.8	40.8	8.6	34.2	35.0
	3	18.1	15.9	33.3	24.2	16.9	35.0	5.7	21.3	18.0
	4	12.2	8.8		14.7	10.0	22.5	3.4	12.1	10.0
	5	6.7	5.7		8.9	6.2	11.7	1.7	7.1	5.8
	6	4.2	3.2		5.8	3.8	3.9	1.0	3.7	3.4
	7	2.3	1.9		3.9	2.3	2.1	0.5	1.8	1.8
	8	1.4	1.2		2.4	1.5	1.3	0.3	1.0	1.1
	9	0.9	0.7		1.6	1.1	0.8	0.2	0.6	0.8
	10	0.6	0.4		1.0	0.8	0.5	0.1	0.4	0.6

Table 4 continued

Si	Dep	09/08 LC	15/08 PR	22/08 PR	05/09 PR	18/09 PR	02/10 PR	16/10 PR
S2	0.2	100.0	100.0	100.0	100.0	100.0	100.0	100.0
	1	52.0	53.3	38.0	40.7	45.5		50.0
	2	24.7	23.3	18.7	19.8	18.2	14.8	22.1
	3	11.7	10.3	8.0	9.2	7.8	9.0	10.4
	4	6.3	5.0	3.3	4.3	3.6	4.6	5.8
	5	3.7	1.8	1.5	2.1	1.5	2.1	3.5
	6	2.8	0.7	0.8	1.1	0.7	1.0	1.9
	7	2.3	0.3	0.5	0.6	0.4	0.5	1.2
	8	1.3	0.2	0.3	0.4	0.2	0.3	0.8
	9	1.1	0.1	0.2	0.3		0.2	0.5
	10	0.9		0.1	0.2			0.3
S3	0.2	100.0	100.0	100.0	100.0	100.0	100.0	100.0
	1	58.3	51.4	82.8	35.6	45.7		68.8
	2	26.7	24.3	54.5	13.8	20.0	15.3	38.1
	3	11.3	12.6	21.0	6.9	9.4	6.8	19.4
	4	5.5	5.7	8.6	3.3	4.6	4.1	8.8
	5	2.5	1.5	4.8	1.7	2.0	2.1	5.2
	6	1.5	0.6	2.0	1.0	0.9	1.0	1.7
	7	1.1	0.3	1.1	0.5	0.4	0.6	1.1
	8	0.8	0.2	0.6	0.3	0.2	0.3	0.9
	9	0.6	0.1		0.2		0.2	0.5
	10	0.4			0.1			0.3

Table 5: Secchi depth (m), 1988. Blanks indicate no data.

Site	24/05	10/06	20/06	04/07	18/07	02/08	15/08	20/09	18/10
N1	3.1	4.0	2.9	3.5	3.0	2.0	2.2		4.2
N2	2.7	4.0	2.9	3.5	2.9	1.8	2.3		3.7
N3	3.0	3.6	2.7	3.2	2.9	1.9	2.3		3.6
S1	3.0	4.0	2.9	3.7	2.5	1.6	2.2		3.8
S2	2.5	3.8	2.8	3.4	2.9	1.8	2.2		4.0
S3	3.0	3.6	2.4	3.1	2.8	1.7	2.2		4.1

Table 6: Secchi depth (m), 1989. Blanks indicate no data.

Site	08/05	17/05	23/05	30/05	06/06	16/06	20/06	08/06	04/07	11/07
N1	2.2	2.2	2.3	2.8	3.1	4.7	5.6	4.8	4.7	5.1
N2	1.9	2.3	2.1	3.2	3.3	5.0	4.8	4.6	5.0	5.0
N3		2.2	2.0	1.8	3.2	4.9		4.6	4.9	4.1
S1	1.9	2.1	2.8	2.8	3.1	5.0	5.3	5.0	4.9	3.7
S2	1.8	2.0	2.6	2.6	2.7	5.0	5.4	4.7	4.3	3.8
S3		2.0	2.5	2.8	2.8	5.2	5.0	4.7	4.5	4.1

Table 6 continued

Site	18/07	25/07	31/07	09/08	15/08	22/08	05/09	18/09	02/10	16/10
N1	3.4	3.4	3.4	2.5	2.1	1.9	2.0	2.3	2.8	3.6
N2	3.5	3.8	3.3	2.4	1.9		2.1	2.0	2.8	3.2
N3	3.6	3.5	3.6	2.5	1.8	2.0	2.0	1.9		3.2
S1	3.7	3.2	3.8	2.0	1.8	1.9	2.1	1.9	2.8	3.7
S2	4.1	2.7	3.4	1.9	1.8	1.9	2.1	2.0	3.2	3.6
S3	4.6	3.1	3.6	1.9	1.9	1.9	2.1	1.8	3.0	3.5

Table 7: Chlorophyll a concentration ($\mu g \cdot L^{-1}$), 1988. Concentrations have been corrected for the presence of phaeopigments. Each concentration is the mean of two replicate samples. Depth = m.

Site	Depth	24/05	10/06	20/06	04/07	18/07	02/08	15/08	20/09	18/10
N1	3.0	3.1	4.6	7.3	10.7	11.6	12.5	10.2	3.7	2.5
	8.0	3.8	1.2	4.3	1.9	3.8	2.1	3.0	3.7	2.3
	18.0	1.1	0.3	0.4	0.6	0.6	0.7	0.0	0.0	2.7
N2	3.0	2.6	5.3	6.2	9.8	11.3	14.1	9.7	3.7	2.4
	8.0	4.6	2.3	3.2	2.0	2.8	2.4	3.4	4.1	2.8
	18.0	1.4	0.4	0.4	0.7	0.5	0.6	0.3	0.1	2.3
N3	3.0	2.4	6.5	5.9	8.7	12.8	17.6	10.3	4.8	3.7
	8.0	1.3	2.5	3.1	1.8	2.7	2.8	3.6	5.1	3.7
	18.0	3.2	0.4	0.4	0.6	0.5	0.6	0.6	0.1	2.9
S1	3.0	2.2	5.6	6.3	7.5	9.8	11.7	8.7	3.4	3.2
	8.0	3.8	2.2	2.9	1.3	1.7	0.7	3.7	2.9	3.6
	18.0	0.7	0.6	0.3	0.6	0.4	0.3	0.4	0.1	0.4
S2	3.0	1.1	5.2	6.9	7.7	13.5	12.8	9.6	3.6	3.5
	8.0	4.6	1.7	3.0	1.5	2.6	1.5	2.9	3.0	3.0
	18.0	2.6	0.3	0.6	0.6	0.4	0.5	0.4	0.0	0.8
S3	3.0	2.0	5.2	5.5	8.7	11.3	14.1	10.0	3.2	3.2
	8.0	2.7	1.8	3.0	1.6	2.2	1.4	1.6	3.9	3.3
	18.0	1.0	0.2	0.8	0.3	0.3	0.9	0.5	0.1	1.2

Table 8: Chlorophyll a concentration ($\mu g \cdot L^{-1}$), 1989. Concentrations have been corrected for the presence of phaeopigments. Each concentration is the mean of two replicate samples. Depth = m. Blanks indicate no data.

Site	Depth	08/05	17/05	23/05	30/05	06/06	16/06	20/06	28/06	04/07	11/07
N1	3.0	7.6	6.2	7.2	3.8	3.6	2.3	2.1	2.5	2.9	3.0
	5.5	5.4	8.6	7.2	4.5	6.1	3.7	2.2	2.6	3.5	3.5
	8.0	6.2	7.5	5.5	5.0	5.1	2.1	1.6	2.7	1.7	2.3
	10.5	6.7	5.5	3.8	3.3	5.3	2.0	0.9	1.8	1.3	1.6
	13.0	6.4	5.3	3.6	2.9	4.2	1.9	1.0	1.1	0.8	1.0
	18.0	5.3	4.5	2.9	1.9	3.0	1.5	1.1	0.7	0.6	0.6
N2	3.0	10.4	7.3	6.2		3.2	2.1	2.4	2.6	2.9	2.2
	5.5	6.8	9.8	6.7		5.0	3.5	2.5	3.2	2.7	3.1
	8.0	6.7	7.1	6.2		5.1	2.1	2.4	1.9	1.4	1.2
	10.5	6.0	6.4	5.0		4.3	1.9	0.9	1.5	1.3	0.9
	13.0	5.5	5.6	3.8		3.6	1.7	1.0	0.7	1.0	0.8
	18.0	5.1	4.4	2.9		2.1	1.6	0.9	0.5	0.7	0.9
N3	3.0	9.6	6.4	8.7	3.1	3.0	2.8	2.3	2.4	3.1	2.6
	5.5	9.8	8.8	8.8	2.8	5.1	3.6	3.2	3.0	3.5	3.8
	8.0	5.4	5.4	8.4	3.8	3.8	1.9	2.4	2.1	1.7	2.3
	10.5	6.2	4.9	5.6	2.2	3.0	2.2	1.4	1.2	1.2	1.4
	13.0	5.1	3.9	4.9	1.9	2.9	2.3	0.9	0.5	0.8	1.2
	18.0	4.1	3.3	4.5	1.6	1.9	1.5	0.9	0.3	0.6	0.8

Table 8 continued

Site	Depth	18/07	25/07	31/07	09/08	15/08	22/08	05/09	18/09	02/10	16/10
N1	3.0	3.3	3.9	3.9	7.1	3.7	6.7	8.8	5.3	6.4	4.3
	5.5	4.9	5.0	5.2	6.8	5.5	3.7	7.9	4.7	5.6	3.6
	8.0	3.1	3.7	4.5	2.8	2.1	1.3	1.7	4.1	5.8	3.8
	10.5	1.6	2.1	2.4	2.1	1.4	0.8	0.8	1.2	5.7	3.9
	13.0	1.0	1.1	1.4	1.4	1.2	0.5	0.6	0.9	5.2	3.5
	18.0	0.9	1.3	1.1	1.2	1.0	0.5	0.3	0.4	1.0	3.9
N2	3.0	3.7	4.0	3.3	5.7	3.9	5.7	6.6	6.9	5.8	4.1
	5.5	4.5	5.3	5.1	5.2	7.3	4.2	6.3	6.8	5.1	4.0
	8.0	2.5	3.6	3.4	2.1	2.1	1.5	1.3	3.9	5.1	3.7
	10.5	2.0	1.9	1.7	1.3	1.6	1.0	0.8	1.4	5.1	3.3
	13.0	1.3	1.7	1.3	1.5	1.3	0.8	0.8	1.3	5.0	4.0
	18.0	1.1	1.6	1.2	1.3	1.1	0.8	0.6	0.9	0.8	4.0
N3	3.0	3.5	4.3	4.6	7.2	4.3	7.1	7.9	6.6	7.7	4.6
	5.5	4.8	5.9	6.0	4.8	6.7	5.5	6.5	6.5	6.8	4.2
	8.0	3.2	3.9	4.4	2.8	2.1	2.0	1.6	4.5	5.2	4.1
	10.5	2.1	2.5	3.1	2.0	1.8	1.3	1.2	1.8	2.5	4.0
	13.0	1.5	1.9	1.9	1.8	1.4	0.8	0.8	1.2	1.6	4.4
	18.0	0.9	1.6	1.5	1.3	1.2	1.1	0.7	0.7	0.8	4.4

Table 8 continued

Site	Depth	08/05	17/05	23/05	30/05	06/06	16/06	20/06	28/06	04/07	11/07
S1	3.0	6.5	3.4	5.4	3.5	3.3	1.9	1.6	2.3	2.6	3.0
	5.5	4.5	6.4	5.6	3.4	5.1	3.6	1.9	2.3	3.9	3.7
	8.0	2.3	7.0	3.9	3.4	4.1	2.2	1.9	1.8	2.3	2.5
	10.5	1.9	5.8	2.3	5.1	2.6	3.4	1.4	1.0	1.5	1.9
	13.0	2.0	4.4	2.3	5.0	3.2	2.3	0.9	1.0	0.9	1.5
	18.0	1.5	2.9	2.6	2.0	2.0	1.5	1.4	0.5	0.3	0.6
S2	3.0	6.2	5.4	6.0	4.4	3.5	2.1	1.9	2.6	2.7	2.8
	5.5	4.7	7.3	5.5	4.9	6.1	3.3	2.5	2.9	3.1	3.5
	8.0	2.9	10.7	4.2	5.9	5.2	2.6	2.3	1.7	2.8	2.3
	10.5	2.0	6.2	4.7	6.1	3.3	2.6	1.3	1.1	1.4	2.0
	13.0	1.3	4.5	2.8	4.6	2.0	2.7	1.2	0.8	0.7	1.1
	18.0	0.8	2.5	2.3	1.8	1.7	1.6	1.4	0.3	0.3	0.2
S3	3.0	9.9	4.1	6.0	5.5	3.5	2.4	1.7	2.4	3.1	3.0
	5.5	9.7	4.9	6.5	6.3	4.4	3.5	1.8	2.6	3.5	4.0
	8.0	5.9	8.5	5.3	5.9	5.2	3.1	1.3	1.8	3.1	2.9
	10.5	4.5	5.5	4.3	5.2	4.4	2.4	1.1	0.8	1.3	1.6
	13.0	3.9	4.7	3.3	3.6	3.4	2.9	0.8	0.4	1.0	1.2
	18.0	2.6	2.4	1.9	2.0	1.8	2.3	1.1	0.2	0.5	0.6

Table 8 continued

Site	Depth	18/07	25/07	31/07	09/08	15/08	22/08	05/09	18/09	02/10	16/10
S1	3.0	4.2	3.9	5.1	7.4	5.1	6.2	7.5	7.4	7.7	4.4
	5.5	5.1	6.2	6.9	4.7	7.4	5.5	5.1	7.9	6.9	4.1
	8.0	3.2	3.6	2.8	2.1	1.9	2.0	1.0	6.5	6.4	4.1
	10.5	2.4	1.9	3.2	2.1	1.6	1.4	0.6	1.0	6.3	3.9
	13.0	1.8	1.3	0.9	1.7	1.4	1.0	0.5	0.6	1.7	4.0
	18.0	0.8	1.1	1.2	0.8	1.2	1.2	0.1	0.5	0.4	3.9
S2	3.0	4.0	3.6	4.4	6.2	4.8	7.5	7.5	7.0	7.3	3.7
	5.5	4.7	5.6	5.8	4.4	11.0	5.2	5.5	7.2	5.4	3.7
	8.0	3.0	3.9	3.9	2.0	1.9	1.8	1.2	6.3	6.8	3.7
	10.5	2.4	2.3	1.9	2.1	1.5	1.4	0.7	1.0	7.0	3.6
	13.0	1.5	1.6	1.3	1.7	1.5	1.1	0.5	0.5	6.3	3.6
	18.0	0.4	1.1	1.0	1.1	1.0	1.0	0.4	0.4	0.4	1.4
S3	3.0	2.8	3.8	3.4	8.4	5.1	7.1	7.5	8.9	7.5	4.4
	5.5	5.0	4.8	4.7	5.8	9.7	6.4	5.1	8.6	7.2	4.0
	8.0	2.3	4.2	3.9	2.7	2.0	2.5	1.5	8.6	6.3	4.0
	10.5	1.9	2.1	2.0	2.6	1.7	1.9	1.0	1.7	5.9	4.2
	13.0	1.1	1.5	1.5	2.1	1.7	1.5	0.6	1.0	3.7	3.8
	18.0	0.9	0.9	1.1	1.2	1.1	1.3	0.7	0.8	0.7	3.1

Table 9: Phaeopigment concentration ($\mu g \cdot L^{-1}$), 1988. Each concentration is the mean of two replicate samples. Depth = m.

Site	Depth	24/05	10/06	20/06	04/07	18/07	02/08	15/08	20/09	18/10
N1	3.0	2.3	4.5	1.3	1.1	5.5	6.8	7.1	5.2	3.9
	8.0	3.9	3.0	2.2	1.3	2.2	2.2	3.1	5.3	4.1
	18.0	1.7	1.5	0.6	0.5	0.9	0.9	0.6	0.6	2.7
N2	3.0	2.2	4.3	3.5	1.0	7.0	4.7	5.8	5.1	3.1
	8.0	2.7	1.5	2.9	1.3	2.8	2.5	4.1	4.1	2.7
	18.0	1.7	1.1	0.7	0.6	0.6	1.0	0.6	0.5	3.6
N3	3.0	2.2	2.6	3.2	1.5	5.3	7.8	8.4	3.5	2.2
	8.0	2.2	2.2	2.8	1.1	2.7	2.2	3.6	2.8	2.2
	18.0	3.1	1.5	0.7	0.6	0.8	0.7	1.4	0.5	2.7
S1	3.0	2.6	3.7	3.3	3.9	5.1	7.3	3.4	2.3	3.6
	8.0	5.0	2.2	3.0	1.7	3.3	2.1	1.8	1.3	2.6
	18.0	2.1	1.0	0.6	0.4	0.6	1.1	0.5	0.2	0.1
S2	3.0	1.8	3.8	2.8	3.5	5.5	6.3	2.8	2.0	2.5
	8.0	4.1	2.7	3.0	1.3	2.4	2.1	1.9	2.7	2.9
	18.0	2.4	1.5	0.4	0.4	0.4	1.1	1.1	0.3	0.6
S3	3.0	2.5	4.3	2.1	4.3	6.5	5.3	3.1	2.5	3.1
	8.0	5.1	2.5	2.0	1.4	2.0	1.7	2.0	1.8	2.3
	18.0	2.1	1.6	0.5	0.3	0.7	1.1	0.6	0.3	1.2

Table 10: Phaeopigment concentration ($\mu g \cdot L^{-1}$), 1989. Each concentration is the mean of two replicate samples. Depth = m. Blanks indicate no data.

Site	Depth	08/05	17/05	23/05	30/05	06/06	16/06	20/06	28/06	04/07	11/07
N1	3.0	14.2	1.9	3.0	1.4	1.5	0.7	0.9	1.1	0.6	0.4
	5.5	16.1	5.2	2.8	2.6	2.0	1.2	0.8	1.1	0.7	1.2
	8.0	6.9	6.9	3.6	2.5	2.3	1.1	1.1	0.3	1.0	1.1
	10.5	5.7	6.5	4.9	2.2	1.7	1.4	0.9	0.2	1.0	1.4
	13.0	5.3	5.9	4.8	1.7	1.7	1.3	0.8	0.4	0.8	1.0
	18.0	4.1	5.2	4.7	2.1	1.2	1.4	1.3	0.2	1.0	1.0
N2	3.0	7.9	3.3	2.9		1.0	1.3	1.0	0.2	0.8	0.6
	5.5	5.8	5.1	3.2		2.3	1.5	2.0	0.9	1.2	1.1
	8.0	5.1	6.3	3.3		1.9	1.5	1.4	0.7	1.1	0.9
	10.5	4.3	4.8	4.0		1.9	1.3	1.3	0.1	1.1	0.9
	13.0	5.4	4.4	4.7		1.2	1.3	1.0	0.8	0.9	1.1
	18.0	4.2	4.2	4.3		0.6	1.4	1.2	0.8	0.7	0.6
N3	3.0	5.9	2.9	0.9	1.8	0.0	0.6	1.0	0.5	0.4	0.4
	5.5	6.4	5.3	1.4	2.2	1.1	1.4	2.1	1.6	0.9	0.7
	8.0	5.9	5.0	1.2	3.3	1.6	1.0	1.8	1.4	1.0	0.8
	10.5	3.8	4.3	2.9	2.7	1.3	1.2	1.1	0.7	0.7	0.8
	13.0	3.9	4.5	3.0	2.6	0.7	1.1	1.0	1.0	0.7	0.6
	18.0	3.4	4.7	2.0	2.7	0.8	1.3	1.1	1.0	0.8	0.7

Table 10 continued

Site	Depth	18/07	25/07	31 07	09/08	15/08	22/08	05/09	18/09	02/10	16/10
N1	3.0	0.6	0.9	0.4	1.6	1.1	2.6	2.5	1.5	1.7	2.4
	5.5	1.0	1.2	1.1	1.1	3.1	2.7	2.1	1.7	2.0	2.7
	8.0	0.8	1.4	1.2	1.3	1.3	1.9	1.0	1.7	2.1	2.5
	10.5	0.6	0.7	0.6	0.8	1.3	1.4	0.7	1.0	2.0	2.3
	13.0	0.6	0.7	0.5	0.9	0.8	1.3	0.5	0.6	1.8	2.5
	18.0	0.6	0.7	0.5	0.6	0.8	1.0	0.7	0.8	0.7	1.9
N2	3.0	1.4	0.8	2.9	1.6	0.8	3.0	2.6	2.8	2.5	2.5
	5.5	1.0	1.8	2.4	2.0	2.8	2.7	2.2	3.0	2.5	2.5
	8.0	0.7	0.9	1.5	1.6	0.8	1.6	0.9	1.7	1.8	2.5
	10.5	0.3	0.7	1.3	0.7	0.9	1.1	0.8	0.8	1.9	2.9
	13.0	0.6	0.4	0.7	0.5	0.7	1.2	0.3	0.0	1.5	2.2
	18.0	0.4	0.3	0.6	0.4	0.4	0.8	0.3	0.3	0.8	2.1
N3	3.0	0.2	0.5	0.5	0.8	1.3	2.3	1.8	3.8	2.7	2.4
	5.5	0.9	1.0	1.7	2.3	2.9	2.7	1.8	4.6	3.2	2.0
	8.0	0.6	0.5	1.0	0.9	1.5	1.2	0.6	3.3	4.0	2.1
	10.5	0.7	0.3	0.4	0.6	0.8	0.9	0.2	0.9	1.2	2.4
	13.0	0.3	0.3	0.2	0.4	0.5	0.9	0.3	0.4	0.8	2.3
	18.0	0.4	0.4	0.0	0.1	0.4	0.2	0.3	0.5	0.3	2.2

Table 10 continued

Site	Depth	08/05	17/05	23/05	30/05	06/06	16/06	20/06	28/06	04/07	11/07
S1	3.0	5.3	2.1	2.4	2.2	0.0	0.4	1.2	0.8	0.7	0.5
	5.5	3.6	3.1	2.8	2.0	1.6	0.8	1.2	1.4	0.6	0.6
	8.0	3.0	5.8	3.3	2.3	2.1	1.4	1.2	0.4	0.9	0.8
	10.5	2.9	5.4	4.8	2.0	1.8	1.3	1.0	0.6	0.7	0.5
	13.0	1.9	3.8	4.3	2.5	1.2	1.2	0.8	0.2	0.7	0.5
	18.0	1.3	2.9	3.2	2.3	0.6	1.2	1.1	0.1	0.3	0.3
S2	3.0	6.8	0.2	1.5	1.8	0.6	0.7	0.7	0.3	0.8	0.5
	5.5	3.1	1.3	2.4	2.3	1.4	1.1	1.2	0.8	1.6	0.7
	8.0	2.6	4.2	3.7	2.9	1.7	0.8	1.0	1.0	1.2	0.6
	10.5	2.8	4.1	3.8	2.6	1.5	1.1	1.1	0.7	0.8	0.4
	13.0	2.6	1.9	4.1	2.5	1.6	1.3	0.9	0.4	0.7	0.5
	18.0	2.1	0.8	3.9	2.2	0.5	0.9	1.1	0.2	0.3	0.4
S3	3.0	8.0	2.4	2.6	1.7	0.7	0.8	1.5	0.7	0.2	0.4
	5.5	5.8	2.3	3.3	2.1	1.3	1.1	2.4	1.5	0.7	0.5
	8.0	2.6	5.6	3.8	2.1	1.7	1.3	1.4	1.4	0.8	0.6
	10.5	2.3	4.9	3.9	1.9	1.4	0.9	1.0	0.8	0.7	0.6
	13.0	1.8	4.7	4.2	2.4	1.0	1.0	1.0	0.9	0.5	0.6
	18.0	2.3	2.1	3.2	1.7	0.3	0.9	1.0	0.4	0.3	0.1

Table 10 continued

Site	Depth	18/07	25/07	31 07	09/08	15/08	22/08	05/09	18/09	02/10	16/10
S1	3.0	0.6	0.1	1.0	2.2	1.2	1.9	1.7	6.3	2.3	1.9
	5.5	1.0	0.8	0.6	1.6	2.7	2.3	1.3	5.9	2.8	2.1
	8.0	1.1	0.8	1.6	1.2	1.1	1.1	0.9	2.9	3.2	1.9
	10.5	0.7	0.8	1.1	0.9	0.5	0.3	0.7	0.9	2.4	2.2
	13.0	0.3	0.7	0.9	0.8	0.6	1.0	0.6	0.9	1.3	1.9
	18.0	0.6	0.6	0.4	0.9	0.3	0.6	1.0	0.6	0.7	1.8
S2	3.0	0.9	0.8	1.4	1.5	1.7	1.0	2.1	6.6	2.7	2.0
	5.5	1.3	1.3	2.3	1.6	4.2	1.3	1.7	6.4	1.8	1.9
	8.0	1.1	0.9	1.3	1.0	0.8	0.9	0.8	6.7	2.5	2.0
	10.5	0.6	0.6	1.5	0.8	0.5	0.5	0.5	1.6	2.5	1.9
	13.0	0.8	0.2	0.6	0.6	0.5	0.3	0.7	0.9	2.0	2.0
	18.0	0.6	0.5	0.4	0.4	0.6	0.3	0.5	0.6	0.7	1.3
S3	3.0	0.6	0.8	1.0	0.8	1.2	0.8	1.8	3.1	1.9	1.8
	5.5	1.0	1.2	1.7	1.5	3.4	1.9	1.5	3.4	2.3	2.2
	8.0	0.9	1.3	1.2	0.7	1.6	0.3	0.6	2.6	2.6	2.0
	10.5	0.5	0.6	0.9	0.4	0.4	0.1	0.4	1.1	3.9	1.8
	13.0	0.7	0.4	0.6	0.2	0.4	0.0	0.2	0.4	4.1	2.0
	18.0	0.1	0.1	0.2	0.2	0.6	0.1	0.1	0.1	0.9	1.8

Table 11: Total chlorophyll a concentration ($\mu g \cdot L^{-1}$), 1988. Concentrations are not corrected for the presence of phaeopigments. Each concentration is the mean of two replicate samples. Depth = m.

Site	Depth	24/05	10/06	20/06	04/07	18/07	02/08	15/08	20/09	18/10
N1	3.0	5.3	9.1	8.6	11.8	17.1	19.3	17.3	8.9	6.3
	8.0	7.6	4.2	6.5	3.2	6.0	4.3	6.0	9.0	6.4
	18.0	2.8	1.8	1.0	1.1	1.5	1.6	0.6	0.6	5.4
N2	3.0	4.8	9.6	9.6	10.9	18.2	18.8	15.5	8.8	5.5
	8.0	7.3	3.8	6.1	3.3	5.7	4.9	7.5	8.1	5.5
	18.0	3.1	1.5	1.1	1.3	1.1	1.6	0.9	0.6	5.9
N3	3.0	4.6	9.1	9.1	10.3	18.1	25.4	18.7	8.2	5.9
	8.0	3.5	4.7	5.9	2.9	5.4	5.0	7.2	7.8	5.9
	18.0	6.3	1.9	1.1	1.2	1.3	1.3	2.0	0.6	5.6
S1	3.0	4.9	9.4	9.6	11.4	14.9	19.0	12.1	5.7	6.7
	8.0	8.8	4.4	5.8	3.0	5.0	2.8	5.5	4.2	6.2
	18.0	2.8	1.5	0.9	1.0	0.9	1.4	0.9	0.3	0.6
S2	3.0	2.9	9.1	9.6	11.2	19.0	19.1	12.4	5.7	6.0
	8.0	8.6	4.4	6.0	2.8	5.0	3.6	4.8	5.7	5.9
	18.0	5.0	1.8	1.0	1.0	0.8	1.6	1.5	0.4	1.4
S3	3.0	4.5	9.5	7.6	13.1	17.8	19.4	13.1	5.7	6.3
	8.0	7.8	4.3	4.9	3.1	4.3	3.1	3.5	5.7	5.6
	18.0	3.1	1.9	1.3	0.6	0.9	2.0	1.0	0.5	2.3

Table 12: Total chlorophyll a concentration ($\mu g \cdot L^{-1}$), 1989. Concentrations are not corrected for the presence of phaeopigments. Each concentration is the mean of two replicate samples. Depth = m. Blanks indicate no data.

Site	Depth	08/05	17/05	23/05	30/05	06/06	16/06	20/06	28/06	04/07	11/07
N1	3.0	21.8	8.1	10.1	5.2	5.2	3.0	3.0	3.6	3.5	3.4
	5.5	21.4	13.9	10.0	7.1	8.1	4.9	3.1	3.7	4.1	4.7
	8.0	13.1	14.5	9.1	7.6	7.4	3.2	2.7	3.1	2.7	3.4
	10.5	12.4	12.1	8.7	5.6	7.0	3.4	1.8	2.0	2.2	3.0
	13.0	11.7	11.2	8.4	4.6	5.9	3.2	1.8	1.4	1.6	1.9
	18.0	9.4	9.8	7.6	4.0	4.2	2.8	2.3	0.9	1.6	1.6
N2	3.0	18.3	10.6	9.1		4.3	3.3	3.4	2.8	3.7	2.8
	5.5	12.6	14.9	10.0		7.3	4.9	4.5	4.1	4.0	4.2
	8.0	11.8	13.4	9.4		6.9	3.6	3.7	2.5	2.5	2.1
	10.5	10.3	11.1	9.0		6.2	3.2	2.2	1.7	2.4	1.8
	13.0	10.8	10.0	8.5		4.9	3.0	2.0	1.5	1.9	2.0
	18.0	9.3	8.6	7.2		2.8	3.0	2.1	1.4	1.4	1.4
N3	3.0	15.5	9.3	9.6	4.8	3.1	3.4	3.3	2.9	3.5	3.0
	5.5	16.2	14.0	10.1	5.0	6.2	5.0	5.2	4.7	4.4	4.6
	8.0	11.3	10.4	9.6	7.1	5.4	2.9	4.2	3.5	2.6	3.1
	10.5	9.9	9.2	8.5	4.9	4.3	3.4	2.5	1.9	1.9	2.3
	13.0	8.9	8.4	7.9	4.5	3.7	3.4	1.8	1.5	1.5	1.8
	18.0	7.5	8.0	6.6	4.3	2.7	2.8	2.0	1.3	1.5	1.5

Table 12 continued

Site	Depth	18/07	25/07	31/07	09/08	15/08	22/08	05/09	18/09	02/10	16/10
N1	3.0	3.9	4.8	4.3	8.6	4.7	9.3	11.3	6.9	8.1	6.7
	5.5	5.9	6.2	6.3	7.9	8.6	6.4	10.0	6.4	7.7	6.3
	8.0	3.9	5.1	5.7	4.1	3.5	3.2	2.8	5.8	7.9	6.3
	10.5	2.2	2.8	3.0	3.0	2.7	2.1	1.5	2.3	7.7	6.2
	13.0	1.5	1.8	1.9	2.3	2.0	1.7	1.2	1.5	7.1	6.0
	18.0	1.5	2.0	1.6	1.8	1.8	1.6	1.0	1.1	1.8	5.8
N2	3.0	5.1	4.8	6.2	7.3	4.7	8.8	9.2	9.7	8.3	6.6
	5.5	5.4	7.0	7.4	7.3	10.1	6.9	8.5	9.8	7.5	6.5
	8.0	3.1	4.6	4.8	3.7	2.9	3.1	2.3	5.6	6.9	6.3
	10.5	2.3	2.5	3.0	2.0	2.5	2.1	1.6	2.2	7.0	6.2
	13.0	1.9	2.1	2.0	2.0	2.0	1.9	1.1	1.3	6.5	6.2
	18.0	1.5	1.9	1.9	1.7	1.5	1.6	1.0	1.2	1.5	6.1
N3	3.0	3.7	4.8	5.2	8.0	5.5	9.4	9.8	10.4	10.4	7.0
	5.5	5.7	6.9	7.7	7.1	9.6	8.2	8.3	11.1	10.0	6.2
	8.0	3.8	4.4	5.4	3.7	3.6	3.2	2.2	7.8	9.1	6.2
	10.5	2.8	2.9	3.6	2.6	2.6	2.1	1.4	2.7	3.7	6.4
	13.0	1.8	2.2	2.1	2.2	1.9	1.6	1.1	1.6	2.4	6.7
	18.0	1.3	1.9	1.5	1.5	1.7	1.3	1.0	1.2	1.1	6.5

Table 12 continued

Site	Depth	08/05	17/05	23/05	30/05	06/06	16/06	20/06	28/06	04/07	11/07
S1	3.0	11.9	5.5	7.8	5.7	3.3	2.3	2.7	3.1	3.2	3.5
	5.5	8.1	9.5	8.4	5.4	6.7	4.4	3.2	3.7	4.5	4.3
	8.0	5.3	12.8	7.2	5.8	6.2	3.6	3.2	2.2	3.2	3.4
	10.5	4.8	11.2	7.1	7.1	4.4	4.6	2.4	1.6	2.2	2.5
	13.0	3.9	8.2	6.7	7.5	4.4	3.5	1.7	1.2	1.6	2.0
	18.0	2.8	5.8	5.7	4.3	2.6	2.8	2.5	0.6	0.6	0.8
S2	3.0	13.0	5.6	7.5	6.2	4.1	2.8	2.6	3.0	3.5	3.3
	5.5	7.8	8.6	8.0	7.2	7.5	4.4	3.7	3.7	4.7	4.2
	8.0	5.5	14.9	7.9	8.7	6.9	3.3	3.3	2.7	4.0	2.9
	10.5	4.8	10.3	8.5	8.7	4.8	3.7	2.4	1.8	2.2	2.4
	13.0	3.9	6.4	6.8	7.0	3.6	4.0	2.1	1.2	1.4	1.6
	18.0	2.9	3.2	6.3	4.0	2.2	2.5	2.5	0.5	0.6	0.7
S3	3.0	17.9	6.5	8.5	7.2	4.1	3.2	3.2	3.1	3.3	3.4
	5.5	15.5	7.2	9.8	8.4	5.7	4.6	4.2	4.1	4.2	4.5
	8.0	8.6	14.0	9.1	8.0	6.9	4.4	2.6	3.2	3.8	3.4
	10.5	6.8	10.4	8.1	7.1	5.8	3.3	2.1	1.6	2.1	2.2
	13.0	5.7	9.5	7.5	6.0	4.4	3.8	1.8	1.3	1.5	1.8
	18.0	5.0	4.5	5.1	3.7	2.1	3.2	2.1	0.7	0.8	0.7

Table 12 continued

Site	Depth	18/07	25/07	31/07	09/08	15/08	22/08	05/09	18/09	02/10	16/10
S1	3.0	4.8	4.0	6.0	9.6	6.3	8.1	9.2	13.7	10.0	6.3
	5.5	6.1	7.0	7.5	6.3	10.1	7.8	6.3	13.8	9.7	6.3
	8.0	4.3	4.5	4.3	3.3	3.0	3.1	1.9	9.4	9.6	6.1
	10.5	3.1	2.8	4.3	3.0	2.2	1.8	1.2	1.9	8.7	6.2
	13.0	2.1	2.0	1.8	2.5	2.0	2.0	1.1	1.5	3.0	6.0
	18.0	1.4	1.7	1.6	1.7	1.5	1.8	1.1	1.1	1.1	5.7
S2	3.0	4.8	4.4	5.8	7.7	6.5	8.5	9.6	13.6	10.0	5.7
	5.5	6.0	6.9	8.1	6.0	15.1	6.4	7.2	13.6	7.2	5.6
	8.0	4.1	4.9	5.2	3.1	2.7	2.7	2.0	13.0	9.3	5.7
	10.5	3.0	2.9	3.4	2.9	2.0	1.9	1.2	2.5	9.5	5.5
	13.0	2.3	1.9	1.9	2.3	2.0	1.4	1.1	1.4	8.3	5.6
	18.0	1.0	1.6	1.4	1.5	1.6	1.3	0.9	1.0	1.0	2.6
S3	3.0	3.4	4.6	4.4	9.2	6.4	8.0	9.2	12.0	9.5	6.2
	5.5	6.0	6.0	6.4	7.3	13.1	8.3	6.6	12.0	9.4	6.2
	8.0	3.2	5.5	5.2	3.4	3.5	2.7	2.2	11.2	8.9	5.9
	10.5	2.4	2.7	2.9	2.9	2.2	1.9	1.3	2.8	9.8	5.9
	13.0	1.8	1.9	2.1	2.2	2.0	1.5	0.8	1.4	7.8	5.7
	18.0	0.9	1.0	1.3	1.4	1.8	1.5	0.8	0.9	1.5	4.9

Table 13: Total phosphorus concentration ($\mu g \cdot L^{-1}$), 1988. Water was collected at three depths within each stratum and pooled. Depth = m.

Site	Depth	24/05	10/06	20/06	04/07	18/07	02/08	15/08	20/09	18/10
N2	0- 6	34.5	28.1	28.6	28.2	32.3	29.3	28.9	29.9	51.8
	6-12	49.5	65.0	57.6	65.5	70.6	56.4	69.3	49.9	48.0
	12-18	69.5	83.3	87.6	94.9	105.5	104.7	109.8	114.4	44.5
	18-24	77.5	86.0	91.6	98.7	115.2	118.6	117.3	123.0	108.5
S1	0- 6	33.4	27.6	32.7	29.6	29.7	26.9	27.5	28.6	36.9
	6-12	45.9	45.2	40.8	36.6	46.8	47.6	64.7	65.9	36.5
	12-18	64.6	81.1	85.8	79.8	91.4	98.1	110.4	116.6	107.6
	18-24	83.6	104.8	99.7	105.0	110.8	118.1	124.5	131.0	107.6

Table 14: Total phosphorus concentration ($\mu g \cdot L^{-1}$), 1989. Depth = m.

Site	Depth	08/05	17/05	23/05	30/05	06/06	16/06	20/06	28/06	04/07	11/07
N1	3.0	65.6	51.8	53.5	51.7	25.4	18.7	19.0	20.2	18.9	18.7
	5.5	60.5	57.1	54.9	55.9	26.4	19.4	18.1	20.2	19.3	22.5
	8.0	50.9	52.1	53.1	68.9	36.7	26.7	31.6	27.2	50.2	41.3
	10.5	51.9	59.1	57.3	73.1	39.1	45.7	43.5	45.9	49.8	56.8
	13.0	53.5	60.1	59.0	78.4	43.6	53.6	45.7	51.3	51.5	59.3
	18.0	57.8	57.8	61.9	88.2	54.2	68.4	58.6	67.4	64.0	71.7
N2	3.0	63.8	58.8	54.9	50.5	29.9	14.6	17.1	20.8	18.6	19.0
	5.5	54.9	64.5	55.2	50.2	39.1	18.4	21.2	20.2	33.8	19.0
	8.0	52.9	61.2	54.2	59.7	43.9	27.0	25.0	52.6	56.1	40.9
	10.5	51.9	64.5	58.0	75.8	44.9	42.9	46.3	48.3	50.9	61.1
	13.0	52.6	63.5	60.5	85.2	47.3	56.0	50.1	50.3	56.7	63.5
	18.0	50.6	60.5	65.0	77.5	55.9	58.1	60.8	72.7	64.0	61.1
N3	3.0	56.5	53.5	54.5	55.3	27.5	14.6	18.7	22.2	18.9	16.5
	5.5	56.2	59.1	55.2	57.6	41.2	19.8	17.7	20.8	21.7	18.7
	8.0	49.3	63.2	55.6	67.4	49.7	27.7	19.6	27.9	39.4	44.8
	10.5	47.9	62.8	58.7	101.9	52.8	41.2	32.2	48.3	51.5	52.9
	13.0	50.2	60.5	60.5	100.7	55.5	46.3	36.3	55.3	56.1	57.9
	18.0	50.2	64.2	68.2	103.1	67.5	63.3	52.0	73.1	71.0	70.3

Table 14 continued

Site	Depth	18/07	25/07	31/07	09/08	15/08	22/08	05/09	18/09	02/10	16/10
N1	3.0	21.0	19.7	16.2	21.8	21.0	23.7	22.0	26.3	45.9	56.1
	5.5	22.0	24.6	21.5	24.5	27.4	24.8	21.3	23.0	43.9	56.3
	8.0	36.6	43.9	47.2	49.4	38.7	53.3	42.7	24.3	44.6	56.8
	10.5	66.8	68.2	81.5	89.1	100.6	110.4	104.8	96.0	43.6	55.6
	13.0	68.2	76.1	92.5	102.3	112.7	128.1	109.4	107.1	43.3	55.8
	18.0	76.5	84.8	110.2	107.6	117.5	129.9	115.4	120.0	105.4	55.1
N2	3.0	22.7	19.3	17.7	21.5	22.2	21.8	23.3	29.2	43.9	56.1
	5.5	21.0	24.6	21.8	22.2	28.5	23.3	21.7	27.6	44.3	56.1
	8.0	57.9	50.9	92.5	54.3	47.7	68.3	51.3	25.9	42.3	55.6
	10.5	73.1	64.5	84.2	104.6	90.5	113.0	107.1	87.4	43.9	55.4
	13.0	65.5	69.5	96.6	109.1	110.4	122.4	110.8	108.1	43.3	55.6
	18.0	75.1	84.1	101.2	107.6	115.7	122.0	118.0	115.4	101.6	55.8
N3	3.0	17.3	20.3	17.7	20.7	22.2	21.8	24.0	28.9	44.9	56.5
	5.5	20.7	23.3	21.8	23.0	28.2	22.5	22.0	26.3	41.7	55.4
	8.0	38.3	47.9	49.8	52.8	59.7	57.5	49.7	28.6	39.8	55.8
	10.5	48.6	64.8	75.5	89.1	94.6	108.5	97.9	85.4	74.7	55.6
	13.0	58.9	64.8	90.2	97.4	113.8	112.3	112.7	105.8	89.7	57.3
	18.0	71.5	102.1	103.4	106.1	120.9	127.7	115.0	113.7	104.2	55.8

Table 14 continued

Site	Depth	08/05	17/05	23/05	30/05	06/06	16/06	20/06	28/06	04/07	11/07
S1	3.0	69.4	49.8	47.5	60.9	29.9	12.9	18.7	21.2	20.0	16.5
	5.5	62.1	53.8	54.5	60.9	40.8	17.4	17.7	20.8	20.3	18.0
	8.0	62.8	64.2	58.4	62.7	42.5	21.2	19.6	29.2	17.5	18.7
	10.5	63.1	64.2	61.5	59.7	48.4	39.1	32.2	38.9	39.1	33.1
	13.0	64.1	66.8	61.5	60.0	51.8	44.6	36.3	46.6	47.0	46.6
	18.0	68.0	70.2	65.0	97.5	65.5	62.9	52.0	73.7	61.3	68.5
S2	3.0	71.3	50.4	49.6	82.3	31.6	13.9	17.4	22.5	20.0	18.3
	5.5	61.8	55.8	49.3	82.3	40.1	14.2	16.5	20.2	20.0	18.7
	8.0	60.1	63.5	58.0	77.0	38.4	18.4	21.5	21.8	19.3	21.5
	10.5	61.5	65.2	55.6	82.6	49.7	25.3	31.9	37.2	31.4	30.3
	13.0	62.1	64.8	62.2	84.7	52.1	40.1	40.3	46.6	46.3	48.3
	18.0	69.4	71.9	66.8	119.4	65.5	61.2	53.2	60.7	49.1	68.1
S3	3.0	72.3	48.4	51.7	91.2	27.5	11.5	17.1	21.8	21.7	17.6
	5.5	78.6	54.1	49.3	93.0	34.0	16.7	17.1	18.2	19.6	18.0
	8.0	63.4	61.5	51.7	88.8	36.7	27.0	37.5	25.2	22.7	20.8
	10.5	65.4	67.2	56.6	88.5	39.1	43.9	39.4	41.6	47.7	46.2
	13.0	56.2	66.2	60.8	96.6	47.7	39.4	41.0	49.3	48.1	48.0
	18.0	62.1	73.9	69.9	114.1	63.1	53.6	62.3	70.7	41.4	63.2

Table 14 continued

Site	Depth	18/07	25/07	31/07	09/08	15/08	22/08	05/09	18/09	02/10	16/10
S1	3.0	19.7	17.3	19.6	19.9	19.5	24.8	23.3	29.6	36.6	55.4
	5.5	21.0	24.3	23.3	21.1	31.2	24.0	19.7	28.2	35.6	54.4
	8.0	20.7	34.3	41.1	20.7		22.9	35.5	24.0	37.5	54.4
	10.5	31.3	42.3	38.8	58.9	47.3	69.8	68.0	86.4	38.2	55.1
	13.0	45.2	48.9	78.9	88.6	78.1	72.5	78.9	91.4	77.9	54.4
	18.0	68.8	84.8	74.7	112.1	101.4	119.8	105.5	106.8	103.1	56.4
S2	3.0	19.0	18.0	20.7	22.2	20.3	23.6	22.7	30.5	38.8	56.1
	5.5	21.0	26.0	24.1	20.7	25.2	22.2	19.0	27.9	37.2	56.1
	8.0	23.0	25.3	26.7	26.4	15.8	20.7	23.6	26.9	39.1	55.6
	10.5	31.6	32.3	37.7	54.7	47.7	44.7	50.9	81.5	37.9	55.8
	13.0	44.6	44.6	70.6	60.4	67.6	63.5	64.1	94.0	38.2	54.4
	18.0	63.5	72.5	88.7	81.5	81.9	98.0	102.5	103.8	103.2	75.7
S3	3.0	17.3	18.0	16.9	24.9	20.3	23.3	23.3	27.3	37.9	55.6
	5.5	23.0	34.6	24.1	23.0	27.4	23.3	19.7	28.6	40.4	55.6
	8.0	43.6	32.3	45.3	49.8	22.2	39.4	45.0	25.9	39.5	55.4
	10.5	51.2	59.9	65.3	63.8	68.7	86.4	91.0	71.3	40.1	55.6
	13.0	53.5	64.8	63.4	75.5	80.4	99.9	95.0	94.0	39.1	55.1
	18.0	63.2	62.9	85.7	78.9	88.3	89.0	87.4	97.3	107.4	56.1

Table 15: Nitrite + nitrate concentration ($\mu g \cdot L^{-1}$), 1988. Depth = m. Blanks indicate no data.

Site	Depth	24/05	10/06	20/06	04/07	18/07	02/08	15/08	20/09	18/10
N2	3.0	0.0	0.0	0.5	3.8	1.0		0.0	17.9	27.9
	8.0	3.2	24.8	67.5	53.6	39.2		1.6	9.7	25.9
	18.0	87.5	86.3	226.4	218.4	218.6		225.2	163.2	24.7
S1	3.0	0.0	0.0	0.0	8.1	1.2		0.2	7.3	9.0
	8.0	0.0	14.6	0.0	62.0	43.0		6.6	21.7	12.4
	18.0	112.2	133.8	278.4	216.3	207.4		106.0	131.0	13.7

Table 16: Nitrite + nitrate concentration ($\mu g \cdot L^{-1}$), 1989. Depth = m. Blanks indicate no data.

Site	Depth	08/05	17/05	23/05	30/05	06/06	16/06	20/06	28/06	04/07	11/07
N1	3.0	0.6	0.0	0.0	0.0	0.0	0.0		0.0	0.0	16.7
	5.5	0.2	0.0	0.0	0.0	0.0	0.0	12.6	0.0	0.0	6.0
	8.0	4.1	0.0	0.0	9.0	0.0	7.0		0.0	25.7	57.3
	10.5	13.2	18.7	5.8	38.7	11.5	32.2	30.9	22.7	34.7	98.3
	13.0	42.2	25.3	24.3	51.6	2.1	44.0	30.9	45.2	60.9	96.2
	18.0	0.4	61.1	61.4	72.6	39.9	54.6		54.8	60.4	94.0
N2	3.0	0.0	0.0	0.0	0.0	0.0	0.4		0.0	0.0	8.8
	5.5	31.3	0.0	0.0	0.0	0.0	0.8	1.1	0.0	0.0	5.4
	8.0	38.2	0.0	0.0	0.0	0.0	7.0		24.9	27.4	101.9
	10.5	52.1	57.5	9.4	26.5	0.0	23.8		35.6	29.1	122.2
	13.0	53.0	71.8	26.1	55.7	17.4	43.4	36.6	45.2	46.4	101.9
	18.0	61.6	71.8	77.2	18.3	50.5	55.7	51.5	46.4	69.9	113.7
N3	3.0	0.1	0.0	0.0	0.0	0.0	0.0		0.0	0.0	13.9
	5.5	0.3	0.0	0.0	0.0	0.0	0.0		0.0	0.0	6.5
	8.0	49.6	56.9	0.0	0.0	11.5	10.3	3.4	0.0	23.5	60.1
	10.5	60.9	78.4	15.5	70.3	33.4	9.8		28.3	46.4	86.1
	13.0	66.1	80.2	43.7	70.3	46.4	18.7	27.5	52.6	64.3	79.9
	18.0	73.8	112.4	78.1	72.6	52.9	50.1	46.9	48.6	56.3	149.8

Table 16 continued

Site	Depth	18/07	25/07	31/07	09/08	15/08	22/08	05/09	18/09	02/10	16/10
N1	3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	52.6	41.5
	5.5	0.0	0.0	0.0	0.0	0.0		0.0	0.0	37.8	38.3
	8.0	17.1	12.8	5.5	15.3	22.6	61.2	62.3	0.0	48.6	45.7
	10.5	61.1	50.8	120.7	127.8	107.8	156.7	200.3	138.7	32.6	40.4
	13.0	78.4	93.0	111.1	161.3	187.2	191.2	207.3	186.8	31.5	46.8
	18.0	78.4	91.4	227.5	164.8	192.9	190.0	212.6	197.5	195.6	41.0
N2	3.0	0.0	0.0	0.6	0.0	0.0	0.0	0.0	0.0	32.1	39.4
	5.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	31.5	38.8
	8.0	42.5	11.7	50.7	47.7	43.6	84.5	106.9	3.1	39.5	45.2
	10.5	107.5	75.9	86.3	118.3	123.6	148.9	174.5	145.0	37.8	44.1
	13.0	77.8	80.2	94.2	121.3	145.2	158.4	197.1	193.6	37.8	41.0
	18.0	77.8	79.7	108.6	136.0	187.2	167.8	199.2	183.4	196.7	41.5
N3	3.0	4.6	0.0	0.0	0.0	0.0	0.0	0.0	4.8	25.2	48.9
	5.5	0.0	0.0	0.0	1.2	0.0	0.0	0.0	0.0	24.6	44.7
	8.0	22.7	24.5	20.5	47.7	65.8	44.0	81.7	22.9	33.2	44.7
	10.5	53.0	60.9	82.1	126.0	131.9	134.5	177.7	140.4	145.9	37.8
	13.0	83.4	84.5	114.1	138.9	169.4	167.3	204.1	183.4	195.6	47.8
	18.0	88.3	78.6	18.0	150.1	169.4	186.2	198.1	200.9	197.9	45.2

Table 16 continued

Site	Depth	08/05	17/05	23/05	30/05	06/06	16/06	20/06	28/06	04/07	11/07
S1	3.0	102.1	0.0	0.0	0.0	0.0	1.9		0.0	0.0	7.7
	5.5	56.3	0.0	14.6	0.0	0.0	2.5		0.0	0.0	7.7
	8.0	71.4	30.0	61.4	0.0	0.0	0.0		6.9	0.0	6.5
	10.5	155.6	65.9	82.5	0.0	29.3	2.5		13.1	25.7	17.8
	13.0	152.8	211.6	101.9	0.0	33.4		19.4	43.5	52.0	35.3
	18.0	154.4	145.3	134.5	91.3	33.4	120.2	93.8	211.2	157.6	39.3
S2	3.0	80.9	0.0	0.0	0.0	0.0	0.0		0.0	0.0	7.7
	5.5	102.0	0.0	0.0	0.0	0.0			0.0	0.0	5.4
	8.0	133.0	30.6	48.1	0.0	0.0			0.0	0.0	8.8
	10.5	139.0	64.7	24.3	0.0	26.3			0.0	2.8	20.6
	13.0	140.2	128.6	99.3	0.0	61.2	13.1		17.0	32.4	37.0
	18.0	153.8	158.4	162.8	90.1	119.7			175.1	181.6	6.0
S3	3.0		0.0	0.0	0.0	0.0	0.0		0.0	0.0	6.5
	5.5	44.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.1
	8.0	56.4	0.0	0.0	0.0	0.0		25.2	1.2	3.4	15.0
	10.5	47.2	79.6	44.6	0.0	0.0		34.3	32.8	42.5	44.3
	13.0		83.2	72.8	34.7	29.3		43.5	60.5	76.0	28.5
	18.0		148.9	168.1	104.1	115.0		124.2	216.8	186.7	6.5

Table 16 continued

Site	Depth	18/07	25/07	31/07	09/08	15/08	22/08	05/09	18/09	02/10	16/10
S1	3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.7	43.6
	5.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	41.5
	8.0	0.0	3.1	0.0	0.0	0.0	7.9	1.1	0.0	9.8	47.8
	10.5	22.1	32.0	39.3	92.4	55.0	100.6	126.2	182.8	11.5	44.7
	13.0	51.8	45.4	86.3	96.0	158.0	114.0	161.6	191.9	144.1	42.0
	18.0	155.9	181.3	204.6	189.6	215.8	181.7	205.1	211.1	153.3	41.0
S2	3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.0	48.9
	5.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.3	46.3
	8.0	0.0	0.0	0.0	0.0	0.0	0.0	63.4	0.0	14.3	42.6
	10.5	13.4	1.5	15.7	72.4	42.9	30.1	105.3	160.8	5.2	42.0
	13.0	45.6	53.4	55.5	68.9	123.6	115.6	153.6	233.7	21.2	50.5
	18.0	212.2	241.8	198.0	213.7	211.4	238.9	221.2	220.1	184.2	86.5
S3	3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	14.9	42.0
	5.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	14.9	39.9
	8.0	37.5	21.9	5.5	43.0	31.5	42.3	91.3	0.0	18.3	47.8
	10.5	63.6	73.8	97.8	80.7	116.7		179.9	115.6	22.3	45.2
	13.0	92.1	105.9	116.5	139.5	116.0	170.1	174.5	192.4	19.5	35.1
	18.0	211.0	199.0	199.8	199.0	222.8	214.5	220.2	226.9	200.2	38.3

Table 17: Ammonium concentration ($\mu g \cdot L^{-1}$), 1988. Depth = m. Blanks indicate no data.

Site	Depth	24/05	10/06	20/06	04/07	18/07	02/08	15/08	20/09	18/10
N2	3.0	1.4	5.3	18.6	10.8	6.2	7.7	6.0	3.2	72.5
	8.0	4.5	34.1	23.8	19.4	7.6	8.4	7.8	3.8	51.6
	18.0	109.2	100.2	81.8	30.4	90.1	40.8	49.4	146.1	56.4
S1	3.0	2.7	4.9	22.2	10.8	6.4	6.4	7.1	4.2	5.7
	8.0	3.0	24.3	21.8	14.4	7.2	32.4	13.8	39.0	1.5
	18.0	97.2	85.0	64.8	40.6	64.4	96.0	131.0	208.6	256.6

Table 18: Ammonium concentration ($\mu g \cdot L^{-1}$), 1989. Depth = m. Blanks indicate no data.

Site	Depth	08/05	17/05	26/05	30/05	06/06	16/06	20/06	28/06	04/07	11/07
N1	3.0	9.7	2.6	0.0	0.0	9.0	8.5	6.0	4.0	7.1	16.7
	5.5	21.3	3.4	0.0	0.0	10.1	6.7	4.3	8.6	5.9	6.0
	8.0	22.1	4.1	0.0	0.0	9.5	6.7	35.4	15.0	86.5	57.3
	10.5	25.7	45.2	28.6	23.7	10.7	37.8	54.3	52.5	79.0	98.3
	13.0	29.3	30.4	34.4	39.7	0.0	64.8	57.8	70.9	16.2	96.2
	18.0		26.1	49.6	106.3	10.7	106.7	97.2	127.5	139.0	94.6
N2	3.0		2.1	0.0	0.0	11.8	4.3	2.5	8.0	7.1	8.8
	5.5	26.6	2.1	0.0	0.0	13.0	10.9	9.0	0.0	14.5	5.4
	8.0	23.9	6.4	13.3	0.0	7.2	18.6	12.5	91.7	113.9	101.9
	10.5	21.3	18.7	24.5	0.0	6.6	6.1	105.4	63.4	89.9	122.2
	13.0	23.9	21.8	37.4	60.7	0.0	82.7	82.5	70.9	94.5	101.9
	18.0	21.3	41.5	69.0	78.9	67.7	83.3	114.8	154.6	124.1	113.2
N3	3.0	16.8	5.2	0.0	0.0	7.8	0.1	9.6	7.4	7.7	13.9
	5.5	20.4	9.5	0.0	0.0	11.3	9.7	11.3	9.2	8.2	6.5
	8.0	26.6	25.5	23.3	0.0	6.6	15.1	20.7	0.0	48.2	60.1
	10.5	27.5	30.4	31.5	68.1	21.0	12.1	37.2	56.5	79.6	86.1
	13.0	23.9	40.2	43.8	87.5	45.2	12.1	55.4	96.3	99.6	79.9
	18.0	28.4	51.3	74.2	105.1	119.3	100.1	98.4	162.7	164.1	149.8

Table 18 continued

Site	Depth	18/07	25/07	31/07	09/08	15/08	22/08	05/09	18/09	02/10	16/10
N1	3.0	5.4	9.9	3.8	3.7	9.7	13.2	12.3	9.3	20.3	43.9
	5.5	6.0	5.4	2.6	4.9	9.1	25.1	11.8	8.2	15.8	52.1
	8.0	9.3	7.1	7.4	16.4	10.9	30.8	50.4	8.2	18.6	47.8
	10.5	93.2	53.7	103.2	47.0	54.6	24.1	20.9	56.7	17.5	51.6
	13.0	94.9	99.2	50.5	58.4	53.4	39.6	36.2	53.0	27.6	45.6
	18.0	148.9	139.0	63.1	89.6	80.9	55.1	40.7	63.6	79.6	57.5
N2	3.0	10.5	6.6	6.8	6.7	12.1	12.7	12.8	12.4	18.6	40.7
	5.5	11.6	7.7	9.8	6.7	15.1	29.8	13.3	13.0	22.0	42.3
	8.0	97.7	22.3	80.4	46.4	19.3	50.4	37.7	16.1	23.7	45.6
	10.5	112.3	57.6	128.3	123.8	33.7	70.0	69.7	46.7	23.1	43.4
	13.0	98.8	98.6	124.7	133.4	92.9	71.1	41.8	43.0	27.1	46.7
	18.0	160.1	160.3	161.3	135.2	76.8	72.1	58.0	61.4	68.9	49.9
N3	3.0	6.0	4.9	6.8	6.1	10.3	10.6	12.3	10.9	13.5	38.5
	5.5	6.5	5.4	6.8	4.9	11.5	11.7	11.8	10.3	10.1	40.7
	8.0	14.4	15.5	6.8	30.8	18.7	30.8	57.0	11.4	11.2	45.6
	10.5	49.9	52.6	42.7	52.4	38.4	34.4	28.6	49.8	68.3	47.8
	13.0	78.0	58.8	69.6	54.8	69.0	39.0	39.2	59.3	64.4	39.6
	18.0	128.1	177.2	117.6	90.8	94.1	58.7	48.9	48.8	76.8	39.1

Table 18 continued

Site	Depth	08/05	17/05	26/05	30/05	06/06	16/06	20/06	28/06	04/07	11/07
S1	3.0	26.6	4.6	0.0	0.0	11.3	4.9	0.0	0.0	5.9	7.7
	5.5	17.7	5.2	0.0	0.0	13.0	6.7	7.2	0.0	7.1	7.7
	8.0	21.3	19.3	35.6	0.0	7.2	4.9	10.2	6.9	5.9	6.5
	10.5	23.9	23.0	36.2	0.0	7.2	0.1	6.6	25.9	29.9	17.8
	13.0	27.5	35.9	44.4	0.0	6.1	14.5	17.2	38.6	37.9	35.3
	18.0	47.1	45.2	45.0	60.2	60.8	49.8	37.2	30.0	37.8	39.3
S2	3.0	41.7	8.9	0.0	0.0	10.1		7.2	9.8	4.2	8.2
	5.5	17.7	3.9	0.0	0.0	10.7	9.1	0.0	0.0	3.1	5.4
	8.0	22.1	5.2	31.5	0.0	12.4	15.1	7.8	15.0	4.8	8.8
	10.5	23.9	6.4	33.2	0.0	10.7	0.1	10.7	24.8	17.4	20.6
	13.0	30.2	32.9	40.9	0.0	10.1	12.7	19.6	27.1	43.1	37.0
	18.0		56.8	49.1	37.4	71.7	49.8	33.1	8.6	5.9	6.0
S3	3.0	42.6	10.7	0.0	0.0	14.7	7.3	0.0	5.1	5.9	6.5
	5.5	43.5	7.0	0.0	0.0	15.3	15.1	5.4	74.4	1.4	7.1
	8.0	27.5	10.1	6.9	0.0	8.4	16.9	29.6	8.6	18.5	15.0
	10.5	60.4	32.2	31.5	0.0	11.8	14.5	40.1	33.4	32.2	44.3
	13.0	17.6	41.5	32.7	6.1	6.6	7.9	34.3	46.7	52.2	28.5
	18.0	26.4	3.6	58.4	55.6	66.5	34.8	54.3	31.1	19.1	6.5

Table 18 continued

Site	Depth	18/07	25/07	31/07	09/08	15/08	22/08	05/09	18/09	02/10	16/10
S1	3.0	10.5	4.9	2.0	7.3	11.5	12.7	12.8	10.9	10.7	24.9
	5.5	11.6	5.4	2.0	10.9	15.7	17.4	12.3	11.9	22.0	27.1
	8.0	6.0	4.9	5.6	10.3	12.1	26.1	11.3	14.0	14.1	28.7
	10.5	17.2	17.8	6.8	19.4	19.9	15.3	11.8	16.7	16.3	24.9
	13.0		22.3	13.4	31.4	13.9	9.6	11.3	14.6	32.7	27.1
	18.0		80.1	41.3	75.8	57.6	53.0	41.8	31.4	59.9	30.9
S2	3.0		6.0	4.4	4.9	10.3	10.6	12.8	9.3	11.2	28.7
	5.5		4.9	17.5	6.1	11.5	19.4	12.3	9.3	10.1	29.3
	8.0		5.4	3.8	12.8	11.5	21.0	21.4	9.3	13.5	31.4
	10.5		7.1	6.8	17.6	21.1	22.5	14.3	17.2	15.2	32.5
	13.0	27.9	13.3	8.0	11.5	14.5	13.2	10.8	15.1	21.4	30.3
	18.0	10.5	8.8	22.3	5.5	12.7	15.8	10.8	23.5	63.2	75.5
S3	3.0	10.5	7.1	5.6	6.7	13.3	11.7	15.4	11.4	11.8	29.8
	5.5	12.2	10.0	5.0	6.7	15.7	15.3	14.8	12.4	16.9	32.5
	8.0	35.8	7.1	21.1	22.4	8.5	27.7	29.1	9.3	12.4	17.3
	10.5	51.5	47.5	24.7	17.6	12.7	25.6	24.0	31.9	19.7	32.5
	13.0	44.2	50.3	10.4	19.4	15.1	15.3	12.8	21.9	12.9	33.6
	18.0	12.7	11.1	6.2	15.2	16.3	13.2	11.8	21.9	43.5	36.9

Table 19: Total Kjeldahl nitrogen concentration ($\mu g \cdot L^{-1}$), 1988. Depth = m. Analyses performed at National Water Research Institute, Burlington, ON. Blanks indicate no data.

Site	Depth	24/05	10/06	20/06	04/07	18/07	02/08	15/08	20/09
N2	3.0	705	829	915	1093	1365	986	870	783
	8.0	689	844	804	1326	908	715		890
	18.0	977	833	809	707	726	665	712	658
S1	3.0	707	849	1010	838	998	903	917	976
	8.0	734	814	763	778	771	644	808	780
	18.0	792	759	734		749	718	655	838

Table 20: Total Kjeldahl nitrogen concentration ($\mu g \cdot L^{-1}$), 1989. Depth = m. Analyses performed at National Water Research Institute, Burlington, ON.

Site	Depth	17/05	30/05	16/06	28/06	11/07	25/07	09/08	22/08	18/09
N2	3.0	646	769	742	817	812	771	842	930	1256
	8.0	562	752	696	770	765	713	677	868	746
	18.0	689	783	689	857	739	893	693	782	719
S1	3.0	862	773	727	836	784	785	900	884	1034
	8.0	837	809	704	740	720	736	897	843	925
	18.0	608	808	709	732	714	674	755	836	676

Table 21: Soluble reactive silicon concentration ($mg \cdot L^{-1}$), 1988. Depth = m. Analyses performed at National Water Research Institute, Burlington, ON.

Site	Depth	24/05	10/06	20/06	04/07	18/07	02/08	15/08	20/09	18/10
N2	3.0	1.80	1.54	0.31	0.46	0.98	1.28	1.56	2.52	3.66
	8.0	2.76	2.84	3.03	2.76	2.53	2.36	2.42	2.51	3.58
	18.0	4.14	4.63	4.57	4.73	5.04	4.67	0.47	4.77	3.53
S1	3.0	2.06	1.48	0.45	0.48	0.95	1.23	1.59	2.44	3.14
	8.0	2.49	2.60	2.00	2.96	2.54	3.36	1.59	3.03	3.21
	18.0	4.40	5.31	4.99	4.99	4.60	4.78	5.03	5.22	5.55

Table 22: Soluble reactive silicon concentration ($mg \cdot L^{-1}$), 1989. Depth = m. Analyses performed at National Water Research Institute, Burlington ON. Blanks indicate no data.

Site	Depth	17/05	30/05	16/06	28/06	11/07	25/07	09/08	22/08	18/09
N2	3.0	2.16	2.05	0.96	0.26	0.15	0.42	0.72	1.02	1.91
	8.0	3.15	2.48	2.54	3.22	3.48	2.64	3.31	3.36	2.09
	18.0	3.75	3.60	4.43	4.66	4.24	5.14	4.95	4.73	4.64
S1	3.0	1.92	1.26	0.60	0.23	0.15	0.36	0.83	1.05	1.70
	8.0	3.90	1.41	2.01	2.20	1.95	2.65	2.57	2.76	1.86
	18.0	4.20	3.60	4.14	4.11	4.35	4.52	4.44	4.40	4.20

Table 23: Dissolved oxygen concentration ($mg \cdot L^{-1}$), 1988. Depth = m. Blanks indicate no data.

Site	Depth	24/05	10/06	20/06	04/07	18/07	02/08	15/08	20/09	18/10
N2	3.0	10.4	10.5	12.2	10.5	10.8	11.0	10.0		
	9.0	6.4	5.3	9.4	2.7	1.4	0.9	0.6		
	18.0	4.0	3.9	4.4	2.0	2.4	1.1	0.7		
S1	3.0	15.9	10.3	12.8	10.9	11.5	11.7	10.7		
	9.0	6.6	5.7	4.9	4.3	1.5	0.6	0.6		
	18.0	3.4	1.3	1.4	1.5	1.0	0.7	0.7		

Table 24: Dissolved oxygen concentration ($mg \cdot L^{-1}$), 1989. Depth = m. Blanks indicate n data.

Site	Depth	08/05	17/05	23/05	30/05	06/06	16/06	20/06	28/06	04/07	11/07
N1	3.0					11.1		9.4	9.7	8.5	10.0
	5.5					10.3		9.1	9.6	7.8	9.4
	8.0					10.1		6.0	6.9	5.1	6.0
	10.5					9.0		5.8	5.6	4.5	4.0
	13.0					8.6		5.6	5.6	4.0	4.2
	18.0					6.6		4.9	4.5	3.3	2.7
N2	3.0	11.5	12.9	8.7	12.5		11.0	9.7	9.7	10.0	9.8
	5.5					10.8		9.1	8.4	7.0	9.6
	8.0	9.4	7.8	8.6	10.4		6.6	7.7	6.9	6.7	6.6
	10.5					10.7		5.7	5.5	5.9	5.5
	13.0					8.0		6.2	4.6	5.1	4.7
	18.0	8.9	7.8	6.7	6.9		5.0	5.5	4.2	4.7	3.1
N3	3.0					10.8		9.1	10.0	9.5	9.6
	5.5					9.2		8.4	9.5	8.6	8.7
	8.0					7.5		6.3	6.5	5.4	5.5
	10.5					7.4		5.6	4.7	4.7	4.9
	13.0					7.3		5.5	4.4	4.2	3.9
	18.0					6.1		5.5	3.6	3.0	2.7

Table 24 continued

Site	Depth	18/07	25/07	31/07	09/08	15/08	22/08	05/09	18/09	02/10	16/10
N1	3.0	10.1	9.5	10.1	9.9	9.2	7.9	9.6	8.5	8.6	8.2
	5.5	9.2	9.5	8.3	7.7	4.9	5.2	9.4	8.6	8.2	8.2
	8.0	5.7	4.8	3.6	3.4	3.0	1.0	0.4	8.3	8.2	8.3
	10.5	4.1	3.7	3.1	3.4	2.4	1.8	1.0	2.4	8.6	8.2
	13.0	3.5	3.3	3.0	3.2	2.2	1.6	2.5	2.1	8.2	8.3
	18.0	2.6	3.0		2.5	1.5	1.5	1.4	0.8	2.3	8.1
N2	3.0	10.2	9.4	9.4	10.2	9.8	8.9	10.0	8.8	8.6	8.8
	5.5	9.0	9.3	7.6	6.9	6.1	6.2	9.7	8.9	8.2	8.5
	8.0	6.0	4.8	5.5	3.8	3.5	2.9	2.6	8.0	8.3	8.5
	10.5	5.2	3.3	4.2	3.8	2.6	3.9	3.5	2.2	8.1	8.4
	13.0	4.2	3.2	3.7	3.7	1.7	3.3	2.3	1.8	8.0	8.2
	18.0	3.1	3.2	3.0	3.1	1.6	2.3	2.3	1.9	2.2	8.2
N3	3.0	10.1	9.3	9.4	9.8	9.8	9.4	9.5	9.2	8.9	8.4
	5.5	9.4	9.2	8.1	7.5	5.7	8.2	9.1	9.2	8.8	8.2
	8.0	6.5	5.0	3.6	3.2	2.3	1.7	0.8	8.4	8.6	8.4
	10.5	5.4	3.8	2.7	2.8	2.0	2.2	1.4	3.8	4.9	8.3
	13.0	3.9	3.4	2.5	2.6	1.8	1.9	1.5	3.4	3.6	8.3
	18.0	3.1	2.5	2.2	2.5	1.8	1.7	1.6	1.1	2.2	8.3

Table 24 continued

Site	Depth	08/05	17/05	23/05	30/05	06/06	16/06	20/06	28/06	04/07	11/07
S1	3.0	8.7	13.2	11.6	12.3		10.9	8.7	10.0	9.1	9.6
	5.5					10.9		8.1	9.4	9.2	8.9
	8.0	5.7	7.5	7.8	11.9		6.6	6.6	6.8	6.4	6.2
	10.5					9.4		5.6	6.3	5.2	5.3
	13.0					7.8		5.5	5.5	5.1	4.7
	18.0	4.7	5.3	6.3	6.9		3.5	4.5	3.6	2.9	1.8
S2	3.0					11.4		8.4	10.1	8.8	9.2
	5.5					11.2		8.3	9.2	7.1	9.1
	8.0					10.7		6.0	7.3	6.4	5.7
	10.5					7.9		6.2	6.4	5.4	5.3
	13.0					7.4		6.0	6.0	4.2	4.6
	18.0					6.2		5.1	4.5	3.7	2.0
S3	3.0					11.3		9.1	9.9	9.5	9.7
	5.5					11.2		8.3	9.4	8.4	8.6
	8.0					10.0		6.6	6.9	6.5	6.3
	10.5					9.4		5.9	5.9	4.8	4.9
	13.0					7.8		5.6	5.9	4.7	5.0
	18.0					5.8		4.4	3.6	2.0	3.2

Table 24 continued

Site	Depth	18/07	25/07	31/07	09/08	15/08	22/08	05/09	18/09	02/10	16/10
S1	3.0	9.7	9.6	9.6	10.1	10.0	9.4	9.5	9.1	9.5	8.1
	5.5	8.9	9.2	9.1	7.0	6.3	8.4	8.8	9.1	9.3	8.3
	8.0	5.0	4.8	4.2	3.8	3.6	1.6	2.5	9.0	9.3	8.2
	10.5	4.9	4.1	3.7	2.5	2.8	1.4	0.8	0.5	9.2	8.1
	13.0	4.8	4.0	3.3	2.7	2.3	2.0	1.7	0.4	3.3	8.4
	18.0	1.2	0.6	0.4	0.5	0.2	0.1	0.0	0.0	0.5	8.3
S2	3.0	10.0	9.4	10.0	10.4	9.7	9.4	9.2	9.1	9.0	8.0
	5.5	8.7	9.6	9.4	6.7	8.2	6.7	8.9	9.1	9.3	7.8
	8.0	6.0	5.7	4.8	3.9	2.9	1.8	1.0	9.3	9.3	7.8
	10.5	5.1	4.7	3.8	3.3	2.7	1.9	0.9	1.1	9.1	7.7
	13.0	4.6	4.0	3.6	2.2	2.5	1.9	1.1	0.3	8.8	7.9
	18.0	2.2	1.7	0.8	1.8	1.2	0.0	0.0	0.2	0.4	3.5
S3	3.0	9.8	9.6	10.0	10.4	9.5	9.1	9.5	9.1	8.9	8.2
	5.5	8.9	9.0	9.1	7.3	7.3	7.9	8.8	9.1	8.9	8.2
	8.0	5.0	4.6	4.1	3.9	2.5	1.4	0.6	9.1	8.8	8.1
	10.5	4.0	3.5	4.0	3.1	2.2	1.3	0.4	3.4	8.7	8.1
	13.0	3.8	2.9	3.3	2.3	2.2	1.2	0.6	0.6	8.7	8.0
	18.0	2.8	2.3	1.9	2.0	0.7	0.6	0.1	0.0	8.4	7.7

Table 25: pH, 1989. Depth = m.

Site	Depth	17/05	23/05	30/05	06/06	16/06	20/06	28/06	04/07	11/07
N1	3.0	8.0	8.2	8.1	8.7	8.6	8.4	8.7	8.8	8.8
	5.5	8.0	8.2	8.4	8.4	8.2	8.4	8.6	8.5	8.5
	8.0	8.0	8.1	8.0	8.4	7.8	7.6	7.8	8.4	7.8
	10.5	7.9	7.9	8.0	8.0	7.4	7.5	7.6	7.6	7.8
	13.0	7.9	8.0	7.9	7.9	7.7	7.4	7.8	7.6	7.7
	18.0	7.9	7.8	7.8	7.8	7.7	7.4	7.6	7.4	7.5
N2	3.0	8.0	8.2	8.4	8.7	8.5	8.4	8.7	8.8	8.8
	5.5	8.0	8.1	8.4	8.2	8.2	8.3	8.3	8.3	8.7
	8.0	7.9	8.0	8.1	8.0	7.8	7.7	7.9	7.7	7.7
	10.5	7.9	7.9	8.0	7.9	7.8	7.5	7.7	7.6	7.6
	13.0	7.9	7.8	7.9	7.8	7.8	7.4	7.7	7.5	7.7
	18.0	7.9	7.7	7.8	7.7	7.7	7.4	7.6	7.1	7.6
N3	3.0	8.2	8.2	8.3	8.6	8.5	8.4	8.8	9.2	8.8
	5.5	7.9	8.1	8.4	8.1	8.3	8.1	8.2	9.1	8.5
	8.0	7.8	7.9	8.2	7.9	7.9	7.7	8.0	8.8	7.8
	10.5	7.9	7.8	7.9	7.7	7.8	7.5	7.4	7.6	7.7
	13.0	7.8	7.8	7.9	7.7	7.7	7.4	7.8	7.4	7.7
	18.0	7.8	7.7	7.8	7.7	7.6	7.4	7.6	7.4	7.6

Table 25 continued

Site	Depth	18/07	25/07	31/07	09/08	15/08	22/08
N1	3.0	8.9	8.9	8.9	8.9	9.0	8.8
	5.5	8.7	8.8	8.5	8.4	8.2	8.3
	8.0	7.9	7.7	7.9	7.7	7.7	7.6
	10.5	7.6	7.8	7.5	7.6	7.5	7.6
	13.0	7.5	7.7	7.4	7.6	7.4	7.6
	18.0	7.5	7.5	7.3	7.5	7.4	7.6
N2	3.0	8.9	8.9	8.9	8.8	9.0	8.8
	5.5	8.6	8.6	8.6	8.2	8.4	8.3
	8.0	7.8	7.8	7.6	7.7	7.5	7.6
	10.5	7.5	7.6	7.5	7.6	7.4	7.6
	13.0	7.5	7.6	7.5	7.6	7.3	7.6
	18.0	7.5	7.7	7.4	7.5	7.5	7.6
N3	3.0	8.9	8.9	9.0	8.8	9.0	8.8
	5.5	8.6	8.6	8.6	8.3	8.3	8.7
	8.0	7.8	7.7	7.7	7.7	7.7	7.8
	10.5	7.7	7.6	7.5	7.6	7.5	7.6
	13.0	7.5	7.6	7.3	7.6	7.4	7.7
	18.0	7.5	7.5	7.2	7.5	7.4	7.6

Table 25 continued

Site	Depth	17/05	23/05	30/05	06/06	16/06	20/06	28/06	04/07	11/07
S1	3.0	8.5	8.4	8.4	8.7	8.6	8.4	8.7	8.7	8.8
	5.5	8.3	8.0	8.3	8.3	8.4	8.1	8.2	8.5	8.6
	8.0	8.0	7.9	8.4	8.1	7.9	7.7	7.9	7.8	7.8
	10.5	7.9	7.8	8.2	7.9	7.9	7.6	7.8	7.5	7.8
	13.0	7.8	7.8	8.2	7.8	7.8	7.6	7.8	7.4	7.8
	18.0	7.9	7.7	7.9	7.7	7.6	7.4	7.7	7.3	7.6
S2	3.0	8.3	8.4	8.5	8.7	8.6	8.5	8.7	8.8	8.8
	5.5	8.2	8.4	8.4	8.5	8.4	8.0	8.4	8.4	8.6
	8.0	8.1	7.9	8.2	8.2	8.0	7.7	7.9	7.7	7.8
	10.5	8.0	7.9	8.2	7.9	7.9	7.6	7.8	7.5	7.8
	13.0	7.8	7.8	8.1	7.8	7.8	7.5	7.8	7.5	7.7
	18.0	7.8	7.7	7.8	7.7	7.7	7.4	7.7	7.4	7.6
S3	3.0	8.5	8.4	8.4	8.6	8.6	8.4	8.7	8.8	8.5
	5.5	8.4	8.3	8.0	8.6	8.4	8.1	8.3	8.3	8.5
	8.0	8.2	8.0	8.2	8.2	7.9	7.6	7.8	7.8	7.9
	10.5	7.9	7.9	8.2	8.1	7.8	7.5	7.7	7.5	7.7
	13.0	8.0	7.8	8.0	7.9	7.8	7.5	7.5	7.4	7.8
	18.0	7.8	7.7	7.8	7.7	7.7	7.3	7.6	7.3	7.6

Table 25 continued

Site	Depth	18/07	25/07	31/07	09/08	15/08	22/08
S1	3.0	8.9	8.9	9.0	8.9	8.9	8.8
	5.5	8.6	8.5	8.7	8.3	8.5	8.6
	8.0	7.8	7.8	7.8	7.7	7.8	7.7
	10.5	7.7	7.6	7.6	7.6	7.6	7.6
	13.0	7.5	7.7	7.5	7.6	7.6	7.6
	18.0	7.4	7.6	7.4	7.5	7.4	7.6
S2	3.0	8.9	8.9	8.9	8.9	8.9	8.8
	5.5	8.4	8.6	8.6	8.3	8.7	8.5
	8.0	7.9	7.9	7.8	7.7	7.8	7.7
	10.5	7.7	7.8	7.7	7.6	7.6	7.7
	13.0	7.7	7.7	7.6	7.7	7.5	7.6
	18.0	7.6	7.6	7.5	7.6	7.4	7.5
S3	3.0	9.0	8.9	8.9	8.9	8.9	8.8
	5.5	8.6	8.5	8.5	8.5	8.6	8.5
	8.0	7.8	7.8	7.8	7.7	7.7	7.6
	10.5	7.6	7.7	7.5	7.7	7.5	7.5
	13.0	7.6	7.7	7.5	7.7	7.5	7.4
	18.0	7.5	7.7	7.4	7.6	7.4	7.4

Table 26: Alkalinity (mg $CaCO_3 \cdot L^{-1}$), 1989. Depth = m.

Site	Depth	17/05	30/05	16/06	28/06	11/07	25/07	09/08	22/08
N1	3.0	165.8	166.6	163.9	162.3	157.9	154.0	155.0	148.0
	5.5	168.1	165.5	165.1	163.4	162.4	158.3	161.6	156.1
	8.0	165.7	164.9	167.0	165.3	164.9	166.0	169.0	168.1
	10.5	164.7	166.9	166.6	163.7	165.3	163.4	169.1	168.1
	13.0	165.9	164.8	165.8	165.5	165.5	165.5	168.4	167.6
	18.0	165.3	165.3	167.3	167.2	166.0	165.8	167.9	167.4
N2	3.0	166.6	164.4	164.6	162.0	160.0	153.4	154.0	146.6
	5.5	165.2	164.4	165.6	163.7	159.6	160.9	163.0	154.4
	8.0	165.3	163.9	165.9	165.6	163.5	166.0	166.5	166.6
	10.5	165.3	164.5	165.9	167.7	164.8	166.6	168.1	167.2
	13.0	165.5	164.4	165.8	166.0	165.2	165.9	169.5	166.5
	18.0	166.5	165.0	166.0	166.2	166.3	167.0	169.1	166.9
N3	3.0	164.4	163.2	164.1	162.4	159.0	155.5	154.0	147.3
	5.5	164.6	164.2	164.2	165.9	161.3	160.6	162.3	149.5
	8.0	164.6	164.5	165.9	166.9	164.4	164.9	168.3	166.9
	10.5	164.7	164.6	165.8	168.0	164.4	167.0	168.1	166.7
	13.0	165.1	164.8	165.2	166.9	164.8	166.5	168.3	166.9
	18.0	164.5	165.1	166.0	166.7	165.3	168.0	169.1	168.3

Table 26 continued

Site	Depth	17/05	30/05	16/06	28/06	11/07	25/07	09/08	22/08
S1	3.0	164.8	164.1	163.4	162.8	159.2	154.6	155.3	147.8
	5.5	163.8	162.0	164.1	164.6	161.0	163.0	163.5	149.0
	8.0	164.1	163.4	164.8	166.0	164.9	166.0	167.2	166.0
	10.5	164.1	163.8	164.5	166.2	164.2	165.6	168.0	165.5
	13.0	164.6	161.8	164.9	165.8	165.3	166.5	167.7	163.2
	18.0	164.2	163.0	165.8	165.6	165.3	166.2	167.4	164.6
S2	3.0	165.2	163.7	163.1	162.7	156.9	155.8	154.4	147.3
	5.5	164.6	164.1	163.8	163.9	158.1	161.6	161.3	151.9
	8.0	163.0	163.9	164.4	164.9	163.0	165.9	167.0	165.8
	10.5	164.4	163.7	164.3	164.6	163.0	166.3	166.6	164.9
	13.0	165.3	163.7	164.8	164.8	162.4	165.5	166.6	165.5
	18.0	167.2	164.1	165.1	165.1	163.9	164.4	166.3	165.1
S3	3.0	165.3	163.1	163.8	161.6	158.8	155.0	154.8	147.4
	5.5	164.9	163.4	163.5	164.6	162.1	161.3	160.6	151.8
	8.0	164.2	163.7	164.8	165.1	164.1	165.6	165.5	167.0
	10.5	164.8	163.1	164.2	165.3	164.6	167.0	166.9	167.3
	13.0	164.6	163.5	164.4	166.3	164.6	165.2	167.9	166.3
	18.0	165.4	164.1	164.5	167.3	163.8	164.9	166.9	165.8

Table 27: Phytoplankton cell counts, 1988. Data are presented as the number of cells (or filaments, for applicable cyanobacteria) per mL of sample.

Taxon	24/05	10/06	20/06	04/07	18/07
Site N2 - 3 m					
Anabaena flos-aquae	5181	699	1988	7940	7868
heterocysts	24	12	0	0	24
Aphanizomen flos-aquae	277	940	1590	807	3157
heterocysts	120	277	313	96	446
Chroococcus sp.	24	24	24	145	169
Gloeocapsa sp.	0	157	169	169	0
Gomphosphaeria sp.	0	0	0	0	2651
Asterionella formosa	506	157	0	0	0
Cyclotella sp. (medium)	133	96	36	24	12
Cyclotella sp. (small)	0	1663	253	0	0
Fragilaria sp.	72	795	1458	36	60
Navicula sp.	12	12	12	0	24
Ankistrodesmus sp.	96	24	108	205	72
Chlorella sp.	60	0	0	0	0
Crucigenia sp.	0	0	0	0	48
Oocystis sp.	0	217	157	120	157
nannoflagellata	1473	1086	2016	724	1034
Cryptomonas sp.	120	96	205	36	0
Rhodomonas sp.	4591	843	675	410	145
Site N2 - 8 m					
Anabaena flos-aquae	145	229	0	410	940
Aphanizomen flos-aquae	0	313	36	96	711
heterocysts	0	84	0	12	169
Chroococcus sp.	0	24	0	24	0
Gloeocapsa sp.	0	96	241	0	0
Gomphosphaeria sp.	0	0	0	0	482

Table 27 continued

Taxon	24/05	10/06	20/06	04/07	18/07
Site N2 - 8 m (continued)					
Asterionella formosa	217	241	12	0	0
Cyclotella sp. (medium)	374	24	96	36	12
Cyclotella sp. (small)	0	241	1530	0	0
Fragilaria sp.	904	374	1904	12	96
Navicula sp.	12	0	12	0	24
Ankistrodesmus sp.	48	0	12	253	0
Chlorella sp.	145	0	0	12	0
Cosmarium sp.	12	0	0	0	0
Crucigenia sp.	48	0	0	0	0
Oocystis sp.	12	60	60	133	36
Scenedesmus sp.	145	24	0	0	12
nannoflagellata	699	289	940	386	301
Cryptomonas sp.	133	24	84	12	36
Rhodomonas sp.	265	84	386	410	84
Site N2 - 18 m					
Anabaena flos-aquae	233	1396	801	0	0
heterocysts	0	52	52	0	0
Aphanizomen flos-aquae	52	26	0	26	52
heterocysts	0	0	0	26	0
Chroococcus sp.	207	0	155	0	0
Gloeocapsa sp.	0	233	0	0	0
Gomphosphaeria sp.	259	0	0	0	0
Asterionella formosa	103	233	26	0	0
Cyclotella sp. (medium)	0	52	0	0	26
Cyclotella sp. (small)	6101	26	0	0	0
Fragilaria sp.	336	52	1215	155	0
Navicula sp.	26	0	0	0	0

Table 27 continued

Taxon	24/05	10/06	20/06	04/07	18/07
Site N2 - 18 m (continued)					
Ankistrodesmus sp.	26	0	0	26	0
Chlorella sp.	259	26	0	0	0
Oocystis sp.	52	103	0	0	26
nannoflagellata	465	259	310	388	78
Cryptomonas sp.	0	26	0	0	78
Rhodomonas sp.	310	181	207	207	78

Table 27 continued

Taxon	02/08	15/08	20/09	18/10
Site N2 - 3 m				
Anabaena flos-aquae	13073	4012	1831	96
heterocysts	0	12	24	0
Aphanizomen flos-aquae	3735	566	48	120
heterocysts	120	120	12	12
Chroococcus sp.	24	145	337	120
Gloeocapsa sp.	1229	0	0	157
Gomphosphaeria sp.	16748	22050	12893	4338
Lyngbya sp.	0	0	48	60
Asterionella formosa	0	0	24	0
Cyclotella sp. (medium)	24	12	12	24
Fragilaria sp.	24	60	12	120
Navicula sp.	0	0	12	0
Ankistrodesmus sp.	48	24	60	36
Chlorella sp.	0	0	36	0
Crucigenia sp.	48	48	0	0
Oocystis sp.	24	48	157	60
Scenedesmus sp.	0	0	12	0
nannoflagellata	5894	1060	1318	1241
Cryptomonas sp.	133	60	96	84
Rhodomonas sp.	663	410	241	217
Site N2 - 8 m				
Anabaena flos-aquae	1892	1036	361	325
heterocysts	0	0	0	12
Aphanizomen flos-aquae	615	181	0	0
heterocysts	12	12	0	0
Chroococcus sp.	0	145	120	120
Gomphosphaeria sp.	3012	13977	5543	11808
Lyngbya sp.	12	0	48	108

Table 27 continued

Taxon	02/08	15/08	20/09	18/10
Site N2 - 8 m (continued)				
Asterionella formosa	0	0	12	12
Cyclotella sp. (medium)	0	12	24	0
Fragilaria sp.	48	12	84	157
Ankistrodesmus sp.	0	108	12	12
Chlorella sp.	0	12	12	12
Cosmarium sp.	0	12	0	0
Oocystis sp.	60	84	48	133
Scenedesmus sp.	0	0	12	0
Staurastrum sp.	0	0	24	0
nannoflagellata	590	277	627	675
Cryptomonas sp.	12	12	84	72
Rhodomonas sp.	241	253	193	277
Site N2 - 18 m				
Anabaena flos-aquae	1241	0	78	233
Aphanizomen flos-aquae	310	155	52	0
heterocysts	78	0	0	0
Chroococcus sp.	0	0	103	155
Gomphosphaeria sp.	1034	1293	1034	2068
Lyngbya sp.	0	0	0	129
Cyclotella sp. (medium)	26	26	0	26
Fragilaria sp.	0	0	0	207
Ankistrodesmus sp.	26	0	0	0
Oocystis sp.	52	0	0	0
nannoflagellata	491	207	284	465
Cryptomonas sp.	0	0	26	52
Rhodomonas sp.	0	103	155	233

Table 27 continued

Taxon	24/05	10/06	20/06	04/07	18/07
Site S3 - 3 m					
Anabaena flos-aquae	132	795	313	6229	2783
Aphanizomen flos-aquae	181	1470	1542	1108	3470
heterocysts	72	470	241	241	590
Chroococcus sp.	24	24	0	0	0
Gloeocapsa sp.	96	337	0	1325	72
Gomphosphaeria sp.	0	0	0	120	3615
Asterionella formosa	241	253	0	12	0
Cyclotella sp. (medium)	132	108	72	72	0
Cyclotella sp. (small)	0	470	783	0	0
Fragilaria sp.	120	952	1205	12	12
Stephanodiscus sp.	24	0	0	0	0
Ankistrodesmus sp.	24	0	84	241	60
Chlorella sp.	0	12	0	0	0
Oocystis sp.	0	0	132	253	60
Scenedesmus sp.	96	0	0	0	0
nannoflagellata	1939	620	1396	336	1060
Cryptomonas sp.	0	60	169	84	48
Rhodomonas sp.	2169	614	1434	289	554
Site S3 - 8 m					
Anabaena flos-aquae	72	687	217	3060	663
Aphanizomen flos-aquae	253	313	132	132	361
heterocysts	84	60	60	60	84
Chroococcus sp.	0	0	0	157	96
Gloeocapsa sp.	48	36	0	301	0
Gomphosphaeria sp.	0	0	0	1807	1928
Asterionella formosa	205	663	24	0	0
Cyclotella sp. (medium)	84	48	120	24	96
Cyclotella sp. (small)	0	446	1157	0	0

Table 27 continued

Taxon	24/05	10/06	20/06	04/07	18/07
Site S3 - 8 m (continued)					
Fragilaria sp.	699	904	2386	0	0
Stephanodiscus sp.	0	12	0	0	0
Ankistrodesmus sp.	36	12	12	0	12
Chlorella sp.	48	24	12	0	0
Oocystis sp.	0	72	72	289	36
Scenedesmus sp.	48	0	0	0	0
nannoflagellata	1181	747	771	157	96
Cryptomonas sp.	24	12	84	36	0
Rhodomonas sp.	1747	494	554	132	96
Site S3 - 18 m					
Anabaena flos-aquae	0	0	0	0	78
Aphanizomen flos-aquae	129	26	0	52	26
Chroococcus sp.	0	0	0	52	0
Gomphosphaeria sp.	1034	258	0	0	0
Asterionella formosa	52	78	103	0	0
Cyclotella sp. (medium)	0	52	0	465	26
Cyclotella sp. (small)	4498	931	801	0	0
Fragilaria sp.	129	0	1112	0	0
Navicula sp.	0	26	26	0	52
Ankistrodesmus sp.	26	78	26	0	0
Chlorella sp.	78	0	26	0	0
Oocystis sp.	155	26	26	0	26
nannoflagellata	4498	181	439	155	155
Rhodomonas sp.	52	78	52	0	52

Table 27 continued

Taxon	02/08	15/08	20/09	18/10
Site S3 - 3 m				
Anabaena flos-aquae	7856	3181	988	48
heterocysts	0	24	24	0
Aphanizomen flos-aquae	3627	422	24	12
heterocysts	144	12	0	0
Chroococcus sp.	169	144	169	0
Gloeocapsa sp.	386	0	0	96
Gomphosphaeria sp.	19520	27954	10121	6506
Lyngbya sp.	0	0	108	36
Cyclotella sp. (medium)	0	0	12	36
Fragilaria sp.	0	0	48	0
Navicula sp.	24	0	0	12
Stephanodiscus sp.	0	0	0	12
Ankistrodesmus sp.	96	24	48	12
Cosmarium sp.	0	12	0	0
Crucigenia sp.	48	48	0	0
Elakatrothrix sp.	0	0	24	0
Oocystis sp.	24	60	48	157
Scenedesmus sp.	0	12	0	0
nannoflagellata	3050	1318	1189	310
Cryptomonas sp.	36	0	48	96
Rhodomonas sp.	783	361	265	229
Site S3 - 8 m				
Anabaena flos-aquae	699	1337	1783	0
Aphanizomen flos-aquae	301	108	72	84
heterocysts	36	0	72	72
Chroococcus sp.	24	0	144	193
Gloeocapsa sp.	0	0	157	0
Gomphosphaeria sp.	1928	4217	7109	3856
Lyngbya sp.	0	0	96	72

Table 27 continued

Taxon	02/08	15/08	20/09	18/10
Site S3 - 8 m (continued)				
Asterionella formosa	0	0	24	24
Cyclotella sp. (medium)	12	0	0	12
Fragilaria sp.	12	0	36	60
Stephanodiscus sp.	0	0	0	12
Ankistrodesmus sp.	0	12	36	0
Crucigenia sp.	0	0	241	0
Oocystis sp.	36	60	60	48
Scenedesmus sp.	0	0	12	0
Staurastrum sp.	0	0	0	24
nannoflagellata	349	169	1157	313
Cryptomonas sp.	36	0	24	24
Rhodomonas sp.	84	108	530	398
Site S3 - 18 m				
Anabaena flos-aquae	0	0	0	439
Aphanizomen flos-aquae	52	78	52	78
heterocysts	26	0	0	0
Chroococcus sp.	0	0	0	103
Gomphosphaeria sp.	1551	517	2068	2068
Lyngbya sp.	0	0	0	26
Asterionella formosa	0	0	26	52
Cyclotella sp. (medium)	78	0	0	0
Cymbella sp.	0	0	26	0
Fragilaria sp.	0	0	26	26
Navicula sp.	26	0	0	0
Chlorella sp.	129	0	26	0
Oocystis sp.	52	78	0	26
nannoflagellata	310	439	543	336

Table 27 continued

Taxon	02/08	15/08	20/09	18/10
Site S3 - 18 m (continued)				
Cryptomonas sp.	26	0	26	0
Rhodomonas sp.	0	26	78	26

Table 28: Phytoplankton cell counts, 1989. Data are presented as the number of cells (or filaments, for applicable cyanobacteria) per mL of sample.

Taxon	17/05	30/05	16/06	28/06	11/07	25/07
Site N2 - 3 m						
Anabaena flos-aquae	0	0	169	1446	1880	12133
heterocysts	0	0	12	0	0	12
Aphanizomenon flos-aquae	0	0	84	72	145	217
heterocysts	0	0	36	24	12	12
Chroococcus sp.	0	0	24	96	0	0
Gloecapsa sp.	0	0	0	0	578	349
Gomphosphaeria sp.	0	0	289	0	0	0
Asterionella formosa	1189	3050	12	0	0	0
Cyclotella sp. (medium)	0	52	0	48	145	48
Cyclotella sp. (small)	36242	1344	145	0	0	0
Fragilaria sp.	1293	1241	253	0	36	12
Navicula sp.	207	103	0	0	0	0
Stephanodiscus sp.	52	0	0	0	0	0
Ankistrodesmus sp.	0	0	916	48	72	36
Chlorella sp.	0	0	0	0	12	0
Crucigenia sp.	0	0	0	96	72	0
Oocystis sp.	0	52	133	615	72	36
nannoflagellata	5015	7859	1470	439	724	2585
Cryptomonas sp.	0	103	169	24	0	0
Rhodomonas sp.	362	155	639	434	289	205
Site N2 - 5.5 m						
Anabaena flos-aquae	0	0	157	723	1940	11350
heterocysts	0	0	12	0	12	24
Aphanizomenon flos-aquae	0	52	84	133	349	795
heterocysts	0	0	72	84	84	133
Chroococcus sp.	0	0	24	96	0	120
Gloecapsa sp.	0	0	0	0	482	313

Table 28 continued

Taxon	17/05	30/05	16/06	28/06	11/07	25/07
Site N2 - 5.5 m (continued)						
Gomphosphaeria sp.	6204	4653	3807	0	0	0
Lyngbya sp.	0	52	0	0	0	0
Asterionella formosa	155	1706	133	0	0	0
Cyclotella sp. (large)	0	0	72	0	0	0
Cyclotella sp. (medium)	0	0	0	133	325	169
Cyclotella sp. (small)	33812	2430	0	0	0	0
Cymbella sp.	0	0	12	0	12	0
Fragilaria sp.	1293	3722	0	0	0	0
Navicula sp.	155	0	0	0	0	0
Stephanodiscus sp.	155	0	0	0	0	0
Ankistrodesmus sp.	0	0	253	169	84	108
Chlorella sp.	0	0	48	0	0	0
Cosmarium sp.	0	0	36	0	0	0
Crucigenia sp.	0	0	48	0	0	0
Oocystis sp.	0	0	133	470	193	169
nannoflagellata	3309	4446	1109	543	595	1008
Cryptomonas sp.	0	103	289	12	12	84
Rhodomonas sp.	52	207	217	699	193	169
Site N2 - 8 m						
Anabaena flos-aquae	0	672	651	120	193	1301
heterocysts	0	0	36	0	0	0
Aphanizomenon flos-aquae	0	52	72	0	48	60
heterocysts	0	52	60	0	12	0
Chroococcus sp.	0	0	0	193	0	0
Gomphosphaeria sp.	259	1551	2024	0	1446	1928
Asterionella formosa	517	1086	84	24	0	0
Cyclotella sp. (large)	0	0	36	0	0	0
Cyclotella sp. (medium)	0	103	0	36	120	145

Table 28 continued

Taxon	17/05	30/05	16/06	28/06	11/07	25/07
Site N2 - 8 m (continued)						
Cyclotella sp. (small)	33140	2327	0	0	0	0
Fragilaria sp.	569	827	24	0	96	0
Navicula sp.	52	155	12	0	0	0
Stephanodiscus sp.	207	52	36	0	0	0
Ankistrodesmus sp.	0	52	96	72	24	48
Oocystis sp.	0	0	48	217	181	36
nannoflagellata	2223	3361	940	517	284	672
Cryptomonas sp.	0	259	205	12	0	12
Rhodomonas sp.	362	207	72	241	145	60
Site N2 - 10.5 m						
Aphanizomenon flos-aquae	0	0	0	0	0	52
heterocysts	0	0	0	0	0	26
Chroococcus sp.	0	0	48	0	0	0
Gomphosphaeria sp.	0	0	0	646	0	0
Asterionella formosa	0	1293	145	52	26	0
Cyclotella sp. (medium)	0	0	0	0	0	26
Cyclotella sp. (small)	24196	5273	205	0	0	0
Fragilaria sp.	155	2016	1554	0	0	0
Navicula sp.	103	0	0	0	0	0
Stephanodiscus sp.	52	103	145	0	0	0
Ankistrodesmus sp.	0	0	0	0	26	26
Chlorella sp.	0	517	0	0	129	0
Oocystis sp.	0	0	0	207	103	103
nannoflagellata	1706	4860	530	181	388	620
Cryptomonas sp.	0	310	60	26	26	0
Rhodomonas sp.	207	310	139	26	103	207

Table 28 continued

Taxon	17/05	30/05	16/06	28/06	11/07	25/07
Site N2 - 13 m						
Anabaena flos-aquae	0	13546	0	0	0	388
heterocysts	0	103	0	0	0	0
Aphanizomenon flos-aquae	0	52	12	0	26	0
Chroococcus sp.	0	0	48	0	0	0
Gomphosphaeria sp.	259	0	0	0	0	0
Oscillatoria sp.	0	0	36	0	0	0
Asterionella formosa	0	1241	133	52	0	0
Cyclotella sp. (medium)	0	103	193	26	78	26
Cyclotella sp. (small)	25592	5170	0	0	0	0
Cymbella sp.	0	0	12	0	0	0
Fragilaria sp.	517	724	518	26	0	0
Navicula sp.	0	52	0	0	0	0
Stephanodiscus sp.	103	52	84	0	0	0
Ankistrodesmus sp.	0	0	60	52	52	0
Chlorella sp.	0	362	157	0	0	0
Oocystis sp.	0	0	26	26	52	259
nannoflagellata	3257	1448	964	362	284	517
Cryptomonas sp.	0	155	24	52	0	0
Rhodomonas sp.	259	259	205	26	52	78
Site N2 - 18 m						
Anabaena flos-aquae	0	0	289	0	388	0
Aphanizomenon flos-aquae	0	0	0	0	52	0
Gomphosphaeria sp.	4550	0	145	0	0	0
Lyngbya sp.	0	0	0	0	26	0
Asterionella formosa	103	827	157	103	52	0
Cyclotella sp. (medium)	0	52	0	0	52	52
Cyclotella sp. (small)	19233	6101	831	0	0	0
Fragilaria sp.	259	982	217	0	26	0

Table 28 continued

Taxon	17/05	30/05	16/06	28/06	11/07	25/07
Site N2 - 18 m (continued)						
Navicula sp.	0	52	12	0	0	0
Stephanodiscus sp.	0	0	84	0	0	0
Ankistrodesmus sp.	0	0	72	0	0	0
Chlorella sp.	0	517	0	0	0	0
Oocystis sp.	0	0	0	181	52	52
Scenedesmus sp.	0	0	36	0	0	0
nannoflagellata	3619	1706	892	78	517	155
Cryptomonas sp.	0	52	12	0	0	0
Rhodomonas sp.	103	52	84	0	0	78

Table 28 continued

Taxon	09/08	22/08	05/09	18/09	02/10	16/10
Site N2 - 3 m						
Anabaena flos-aquae	16134	27677	24122	67126	5904	8157
heterocysts	24	36	72	241	157	193
Aphanizomenon flos-aquae	482	627	229	205	133	386
heterocysts	84	48	24	96	24	48
Chroococcus sp.	289	361	675	554	530	687
Gloecapsa sp.	96	133	0	0	0	0
Gomphosphaeria sp.	2651	7229	241	904	964	2362
Lyngbya sp.	0	0	36	60	48	157
Asterionella formosa	0	24	0	0	0	0
Cyclotella sp. (medium)	0	0	0	12	24	24
Fragilaria sp.	12	0	0	0	36	60
Navicula sp.	12	0	24	0	0	36
Stephanodiscus sp.	0	0	0	0	0	12
Ankistrodesmus sp.	48	12	24	24	24	24
Chlorella sp.	0	0	0	36	12	72
Cosmarium sp.	0	0	0	24	0	0
Crucigenia sp.	96	0	96	0	0	0
Elakatothrix sp.	36	0	0	0	0	0
Oocystis sp.	84	96	0	36	0	96
nannoflagellata	4033	1887	1112	1265	1265	2430
Cryptomonas sp.	36	24	60	120	60	36
Rhodomonas sp.	639	241	410	639	627	771
Site N2 - 5.5 m						
Anabaena flos-aquae	4651	9410	12001	25677	2916	1253
heterocysts	24	48	24	108	60	0
Aphanizomenon flos-aquae	530	627	277	229	265	349
heterocysts	72	24	12	60	120	24
Chroococcus sp.	217	145	578	72	253	0
Gloecapsa sp.	0	48	0	0	0	181

Table 28 continued

Taxon	09/08	22/08	05/09	18/09	02/10	16/10
Site N2 - 5.5 (continued)						
Gomphosphaeria sp.	2771	2651	2289	5314	482	482
Lyngbya sp.	0	0	36	24	36	96
Cyclotella sp. (medium)	0	0	0	12	24	0
Fragilaria sp.	12	0	36	24	36	12
Stephanodiscus sp.	0	0	0	0	0	12
Ankistrodesmus sp.	24	12	12	36	12	36
Chlorella sp.	0	12	0	133	12	36
Cosmarium sp.	0	0	0	60	0	0
Elakatothrix sp.	60	0	24	0	0	0
Oocystis sp.	72	0	24	48	24	12
nannoflagellata	801	1396	1137	1386	1145	1835
Cryptomonas sp.	72	24	12	48	84	24
Rhodomonas sp.	169	120	289	831	422	711
Site N2 - 8 m						
Anabaena flos-aquae	1434	1603	1398	6904	7422	2639
heterocysts	12	0	0	24	229	72
Aphanizomenon flos-aquae	84	96	84	108	193	229
heterocysts	0	0	0	12	60	36
Chroococcus sp.	48	0	145	386	0	0
Gomphosphaeria sp.	602	964	361	4049	1205	0
Lyngbya sp.	0	0	0	0	145	0
Oscillatoria sp.	0	0	0	12	0	0
Cyclotella sp. (medium)	36	0	0	0	12	36
Fragilaria sp.	24	0	0	12	36	48
Ankistrodesmus sp.	12	48	12	36	0	24
Chlorella sp.	0	0	0	48	0	12
Cosmarium sp.	0	0	0	12	0	0

Table 28 continued

Taxon	09/08	22/08	05/09	18/09	02/10	16/10
Site N2 - 8 m (continued)						
Oocystis sp.	60	0	36	84	0	0
nannoflagellata	931	801	517	1313	1313	1629
Cryptomonas sp.	0	12	0	12	48	0
Rhodomonas sp.	145	24	205	410	398	349
Site N2 - 10.5 m						
Anabaena flos-aquae	0	1370	1499	687	5299	2197
heterocysts	0	0	0	0	78	26
Aphanizomenon flos-aquae	0	52	52	12	259	103
heterocysts	0	0	26	0	52	0
Chroococcus sp.	0	103	362	265	103	517
Gloecapsa sp.	0	0	0	0	0	336
Gomphosphaeria sp.	0	0	517	1735	0	0
Lyngbya sp.	0	0	52	24	78	52
Cyclotella sp. (medium)	103	0	0	12	52	0
Fragilaria sp.	0	0	0	12	52	103
Ankistrodesmus sp.	0	0	0	12	0	0
Chlorella sp.	0	0	0	108	52	26
Cosmarium sp.	0	0	26	12	0	0
Oocystis sp.	52	78	26	24	0	52
nannoflagellata	388	336	362	916	2171	1396
Cryptomonas sp.	0	0	0	0	52	26
Rhodomonas sp.	78	181	78	181	388	310
Site N2 - 13 m						
Anabaena flos-aquae	0	879	52	1687	2663	1137
heterocysts	0	0	0	0	207	0
Aphanizomenon flos-aquae	129	26	26	0	336	181
heterocysts	26	0	0	0	129	52

Table 28 continued

Taxon	09/08	22/08	05/09	18/09	02/10	16/10
Site N2 - 13 m (continued)						
Chroococcus sp.	0	0	0	145	0	0
Gomphosphaeria sp.	0	0	0	1253	0	1551
Lyngbya sp.	0	0	0	0	78	155
Cyclotella sp. (medium)	26	26	0	12	0	52
Fragilaria sp.	52	52	0	0	52	52
Stephanodiscus sp.	0	0	0	0	26	0
Ankistrodesmus sp.	0	0	0	36	0	0
Chlorella sp.	0	0	0	24	26	26
Cosmarium sp.	0	0	0	12	0	0
Oocystis sp.	103	0	26	36	26	0
nannoflagellata	543	388	465	831	1810	1267
Cryptomonas sp.	0	0	0	0	52	0
Rhodomonas sp.	181	103	207	193	388	620
Site N2 - 18 m						
Anabaena flos-aquae	439	1060	310	4756	698	1525
heterocysts	0	0	0	0	52	26
Aphanizomenon flos-aquae	52	0	103	155	0	181
heterocysts	0	0	0	52	0	0
Chroococcus sp.	0	0	103	620	310	0
Gloecapsa sp.	0	207	0	0	0	0
Lyngbya sp.	0	0	26	0	26	78
Oscillatoria sp.	0	0	0	52	0	0
Asterionella formosa	0	0	0	0	0	26
Cyclotella sp. (medium)	26	0	0	52	0	52
Fragilaria sp.	26	0	0	0	78	52
Stephanodiscus sp.	26	0	0	0	0	0

Table 28 continued

Taxon	09/08	22/08	05/09	18/09	02/10	16/10
Site N2 - 18 m (continued)						
Ankistrodesmus sp.	0	0	0	0	0	26
Chlorella sp.	0	0	0	52	0	52
Cosmarium sp.	0	0	0	52	0	0
Oocystis sp.	26	26	26	103	0	26
nannoflagellata	259	610	233	1499	1034	853
Rhodomonas sp.	26	103	26	259	0	414

Table 28 continued

Taxon	17/05	30/05	16/06	28/06	11/07	25/07
Site S1 - 3 m						
Anabaena flos-aquae	0	0	13158	1169	8916	14351
heterocysts	0	0	482	0	24	36
Aphanizomenon flos-aquae	52	103	36	84	193	241
heterocysts	0	103	24	36	72	48
Chroococcus sp.	0	0	48	0	48	48
Gloecapsa sp.	0	0	0	313	0	96
Gomphosphaeria sp.	0	0	422	0	0	120
Lyngbya sp.	0	0	0	0	12	0
Asterionella formosa	1137	1603	36	0	0	24
Cyclotella sp. (large)	0	0	36	0	0	0
Cyclotella sp. (medium)	0	103	0	120	217	36
Cyclotella sp. (small)	29935	2792	0	0	0	0
Fragilaria sp.	1086	1499	48	0	361	12
Navicula sp.	207	103	0	0	0	0
Stephanodiscus sp.	0	52	0	0	0	0
Ankistrodesmus sp.	0	0	1301	36	72	84
Chlorella sp.	0	0	48	0	0	0
Crucigenia sp.	0	0	0	48	48	133
Oocystis sp.	0	0	48	229	72	84
nannoflagellata	8117	6463	1012	776	982	827
Cryptomonas sp.	155	207	96	0	24	0
Rhodomonas sp.	827	724	940	217	675	205
Site S1 - 5.5 m						
Anabaena flos-aquae	0	1086	831	96	1374	1506
Aphanizomenon flos-aquae	155	0	12	12	169	422
heterocysts	155	0	0	0	24	72
Chroococcus sp.	103	0	72	48	24	0
Gloecapsa sp.	0	0	0	0	0	374
Gomphosphaeria sp.	0	0	735	241	181	482

Table 28 continued

Taxon	17/05	30/05	16/06	28/06	11/07	25/07
Site S1 - 5.5 m (continued)						
Asterionella formosa	776	1396	205	0	0	0
Cyclotella sp. (large)	0	0	72	0	0	0
Cyclotella sp. (medium)	0	0	0	36	217	96
Cyclotella sp. (small)	32468	2637	0	0	0	0
Fragilaria sp.	1344	982	0	0	0	0
Stephanodiscus sp.	52	155	0	0	0	0
Ankistrodesmus sp.	0	0	398	253	301	217
Cosmarium sp.	0	0	12	0	0	0
Oocystis sp.	0	0	24	277	253	96
nannoflagellata	4550	4395	1675	698	284	698
Cryptomonas sp.	0	259	229	24	36	48
Rhodomonas sp.	465	414	229	542	470	72
Site S1 - 8 m						
Anabaena flos-aquae	0	207	193	0	3012	1024
heterocysts	0	0	0	0	60	0
Aphanizomenon flos-aquae	0	0	0	12	12	289
heterocysts	0	0	0	0	0	48
Chroococcus sp.	0	0	0	24	0	0
Gomphosphaeria sp.	0	0	1928	0	0	0
Asterionella formosa	827	1913	72	0	12	12
Cyclotella sp. (medium)	0	52	0	12	169	48
Cyclotella sp. (small)	47410	4446	301	0	0	0
Fragilaria sp.	1344	2120	337	0	0	0
Navicula sp.	52	103	0	0	0	0
Stephanodiscus sp.	52	0	0	0	0	0
Ankistrodesmus sp.	0	103	84	120	145	60
Chlorella sp.	0	52	24	0	0	0
Oocystis sp.	0	0	60	229	48	96

Table 28 continued

Taxon	17/05	30/05	16/06	28/06	11/07	25/07
Site S1 - 8 m (continued)						
Scenedesmus sp.	0	0	48	0	0	0
nannoflagellata	2844	4033	1446	362	543	465
Cryptomonas sp.	155	259	277	72	12	24
Rhodomonas sp.	517	569	48	36	48	72
Site S1 - 10.5 m						
Anabaena flos-aquae	0	0	108	0	0	155
Aphanizomenon flos-aquae	0	103	0	0	0	52
Chroococcus sp.	0	0	0	52	0	0
Gomphosphaeria sp.	0	0	337	0	0	0
Asterionella formosa	259	1603	157	78	0	0
Cyclotella sp. (medium)	0	52	0	52	129	0
Cyclotella sp. (small)	21249	4188	2699	0	0	0
Cymbella sp.	0	1034	0	0	0	0
Fragilaria sp.	362	0	868	0	0	0
Navicula sp.	52	0	24	0	0	0
Stephanodiscus sp.	0	52	72	0	0	0
Ankistrodesmus sp.	0	52	0	0	26	52
Chlorella sp.	0	207	0	0	0	0
Oocystis sp.	0	0	48	78	155	26
nannoflagellata	2275	4033	1145	362	388	543
Cryptomonas sp.	52	259	0	0	0	0
Rhodomonas sp.	207	52	72	78	26	26
Site S1 - 13 m						
Aphanizomenon flos-aquae	0	0	12	0	0	0
Gomphosphaeria sp.	259	1034	1253	0	0	517

Table 28 continued

Taxon	17/05	30/05	16/06	28/06	11/07	25/07
Site S1 - 13 m (continued)						
Asterionella formosa	207	1448	120	0	26	52
Cyclotella sp. (medium)	21663	0	0	129	155	103
Cyclotella sp. (small)	0	4963	940	0	0	0
Cymbella sp.	52	0	0	0	0	78
Fragilaria sp.	569	2016	506	0	52	259
Navicula sp.	0	155	12	0	0	0
Stephanodiscus sp.	0	103	84	0	0	0
Ankistrodesmus sp.	0	0	0	26	26	78
Chlorella sp.	0	207	0	0	0	155
Oocystis sp.	0	0	24	103	207	129
nannoflagellata	2069	2068	1350	233	284	495
Cryptomonas sp.	0	155	12	0	0	26
Rhodomonas sp.	52	0	72	78	0	78
Site S1 - 18 m						
Anabaena flos-aquae	0	0	217	1835	0	0
Aphanizomenon flos-aquae	0	0	0	26	0	0
Chroococcus sp.	0	0	0	52	0	0
Gomphosphaeria sp.	569	0	0	0	0	0
Asterionella formosa	310	517	217	0	0	0
Cyclotella sp. (medium)	0	0	0	26	78	103
Cyclotella sp. (small)	11995	7083	1084	0	0	0
Fragilaria sp.	52	362	410	0	0	0
Navicula sp.	0	103	12	0	0	0
Stephanodiscus sp.	0	52	145	0	0	0
Ankistrodesmus sp.	0	0	24	0	0	0
Chlorella sp.	0	103	0	0	0	0
Oocystis sp.	0	0	0	26	52	26
Scenedesmus sp.	0	0	24	0	0	0
nannoflagellata	1965	1137	663	259	259	52

Table 28 continued

Taxon	17/05	30/05	16/06	28/06	11/07	25/07
Site S1 - 18 m (continued)						
Cryptomonas sp.	103	52	12	26	0	26
Rhodomonas sp.	0	52	12	78	0	0

Table 28 continued

Taxon	09/08	22/08	05/09	18/09	02/10	16/10
Site S1 - 3 m						
Anabaena flos-aquae	26544	14555	23713	39991	15869	1277
heterocysts	36	48	48	506	458	60
Aphanizomenon flos-aquae	410	566	145	169	446	96
heterocysts	36	60	24	60	84	0
Chroococcus sp.	506	241	530	940	241	0
Gloecapsa sp.	0	193	0	0	0	0
Gomphosphaeria sp.	2410	6989	5723	1928	964	0
Lyngbya sp.	0	36	12	12	133	12
Asterionella formosa	0	0	36	0	0	0
Cyclotella sp. (medium)	0	0	0	0	60	36
Fragilaria sp.	0	36	60	36	217	12
Navicula sp.	0	0	0	0	0	12
Ankistrodesmus sp.	241	24	0	12	12	0
Chlorella sp.	0	12	0	0	24	0
Crucigenia sp.	0	120	96	289	0	0
Oocystis sp.	193	72	12	0	12	12
nannoflagellata	2327	1086	1603	916	1374	569
Cryptomonas sp.	108	0	60	157	72	48
Rhodomonas sp.	181	205	434	530	602	241
Site S1 - 5.5 m						
Anabaena flos-aquae	13025	26364	15314	63607	10097	855
heterocysts	12	48	12	566	313	0
Aphanizomenon flos-aquae	590	590	277	157	542	157
heterocysts	60	36	24	133	72	12
Chroococcus sp.	24	313	1012	651	169	169
Gloecapsa sp.	241	0	361	0	0	0
Gomphosphaeria sp.	2289	4338	783	0	964	0
Lyngbya sp.	0	12	0	24	72	72

Table 28 continued

Taxon	09/08	22/08	05/09	18/09	02/10	16/10
Site S1 - 5.5 m (continued)						
Cyclotella sp. (medium)	0	12	12	12	12	24
Fragilaria sp.	0	24	0	36	12	12
Ankistrodesmus sp.	48	24	60	12	0	12
Chlorella sp.	0	0	0	0	0	24
Cosmarium sp.	0	12	0	0	0	0
Crucigenia sp.	0	96	410	0	0	0
Oocystis sp.	72	36	48	24	0	0
Staurastrum sp.	12	0	0	0	0	12
nannoflagellata	853	0	1163	1337	1277	491
Cryptomonas sp.	60	12	60	108	36	0
Rhodomonas sp.	133	0	133	831	410	361
Site S1 - 8 m						
Anabaena flos-aquae	940	7350	1265	10929	7519	253
heterocysts	0	0	0	24	72	0
Aphanizomenon flos-aquae	60	72	48	241	193	108
heterocysts	0	12	0	48	36	12
Chroococcus sp.	24	72	169	723	265	0
Gloecapsa sp.	0	0	193	0	0	0
Gomphosphaeria sp.	1145	1446	783	169	723	482
Lyngbya sp.	0	0	0	36	72	36
Asterionella formosa	24	0	0	12	12	12
Cyclotella sp. (medium)	84	12	0	0	12	84
Fragilaria sp.	0	12	24	24	96	0
Navicula sp.	0	12	12	0	0	0
Ankistrodesmus sp.	48	24	12	0	12	0
Chlorella sp.	48	0	0	12	0	12
Crucigenia sp.	96	313	0	0	0	0
Oocystis sp.	169	96	24	0	12	0

Table 28 continued

Taxon	09/08	22/08	05/09	18/09	02/10	16/10
Site S1 - 8 m (continued)						
Staurastrum sp.	0	0	0	0	24	0
nannoflagellata	801	414	827	1410	1313	750
Cryptomonas sp.	12	0	24	96	72	24
Rhodomonas sp.	108	36	96	446	578	96
Site S1 - 10.5 m						
Anabaena flos-aquae	931	1939	465	1603	5015	982
heterocysts	0	0	0	0	207	0
Aphanizomenon flos-aquae	52	103	0	52	336	259
heterocysts	0	0	0	0	78	0
Chroococcus sp.	0	52	207	620	0	0
Gloecapsa sp.	0	103	0	0	0	0
Lyngbya sp.	0	0	0	0	103	129
Asterionella formosa	26	0	0	0	0	0
Cyclotella sp. (medium)	0	0	26	0	0	26
Fragilaria sp.	0	52	0	0	26	52
Ankistrodesmus sp.	0	52	0	0	0	0
Chlorella sp.	0	0	0	0	0	52
Crucigenia sp.	0	207	0	0	0	0
Oocystis sp.	0	52	0	0	0	0
Staurastrum sp.	0	52	0	0	0	0
nannoflagellata	259	439	543	982	1267	414
Cryptomonas sp.	0	26	26	0	52	26
Rhodomonas sp.	103	26	129	0	362	284
Site S1 - 13 m						
Anabaena flos-aquae	0	620	776	1810	5299	543
heterocysts	0	0	0	0	259	0

Table 28 continued

Taxon	09/08	22/08	05/09	18/09	02/10	16/10
Site S1 - 13 m (continued)						
Aphanizomenon flos-aquae	26	52	52	52	233	181
heterocysts	0	0	0	0	26	0
Chroococcus sp.	0	0	26	310	0	0
Lyngbya sp.	0	0	0	52	129	284
Asterionella formosa	0	0	26	0	0	0
Cyclotella sp. (medium)	0	26	0	0	26	0
Fragilaria sp.	0	0	0	52	52	52
Navicula sp.	0	26	0	0	0	0
Ankistrodesmus sp.	0	26	0	0	26	0
Chlorella sp.	0	103	0	0	52	78
Cosmarium sp.	0	52	0	103	0	0
Crucigenia sp.	0	284	0	0	0	0
Oocystis sp.	26	52	78	52	0	0
nannoflagellata	439	362	1034	1293	1861	698
Cryptomonas sp.	0	26	0	52	52	0
Rhodomonas sp.	0	52	103	52	155	78
Site S1 - 18 m						
Anabaena flos-aquae	1965	0	905	0	0	0
Aphanizomenon flos-aquae	0	26	26	52	26	129
Lyngbya sp.	0	0	0	0	0	52
Cyclotella sp. (medium)	78	0	26	0	0	52
Fragilaria sp.	0	0	0	0	26	26
Ankistrodesmus sp.	0	26	0	0	0	0
Chlorella sp.	0	0	0	0	26	26
Oocystis sp.	26	78	52	52	0	0
nannoflagellata	0	439	517	259	439	491
Cryptomonas sp.	0	0	26	0	0	0
Rhodomonas sp.	207	52	181	0	26	78

Table 29: Cell volumes ($\mu m^3 \cdot mL^{-1}$) for calculation of biovolumes of phytoplankton taxa. Volumes are for individual cells or filaments.

Group	Taxon	Volume
Cyanobacteria	*Anabaena flos-aquae*	50
	Aphanizomenon flos-aquae	1964
	Chroococcus sp.	65
	Gloeocapsa sp.	85
	Gomphosphaeria sp.	4.2
	Lyngbya sp.	785
	Oscillatoria sp.	
Bacillariophyta	*Asterionella formosa*	560
	Cyclotella sp. (small)	44
	Cyclotella sp. (medium)	141
	Cyclotella sp. (large)	
	Cymbella sp.	160
	Fragilaria sp.	117
	Navicula sp.	310
	Stephanodiscus sp.	497
	Synedra sp.	298
Chlorophyta	*Ankistrodesmus* sp.	16
	Chlorella sp.	150
	Cosmarium sp.	32
	Crucigenia sp.	42
	Elakatothrix sp.	100
	Oocystis sp.	225
	Quadrigula sp.	68
	Staurastrum sp.	4000
	nannoflagellata	11
Cryptophyta	*Cryptomonas* sp.	424
	Rhodomonas sp.	33

Table 30: Phytoplankton biovolume ($\mu m^3 \cdot mL^{-1}$), 1988. The sum of the biovolumes in each group may not equal the total due to rounding errors.

Taxon	24/05	10/06	20/06	04/07	18/07
Site N2 - 3 m					
Anabaena flos-aquae	259057	34943	99405	397019	393405
Aphanizomen flos-aquae	544146	1845363	3122922	1585120	6198527
Chroococcus sp.	1566	1566	1566	9398	10965
Gloeocapsa sp.	0	13314	14338	14338	0
Gomphosphaeria sp.	0	0	0	0	11133
TOTAL CYANOBACTERIA	804769	1895186	3238233	2005876	6614030
Asterionella formosa	283396	87718	0	0	0
Cyclotella sp. (medium)	18688	13591	5097	3398	1699
Cyclotella sp. (small)	0	73162	0	11133	0
Fragilaria sp.	8459	93044	170580	4229	7049
Navicula sp.	3735	3735	3735	0	7470
TOTAL BACILLARIOPHYTA	314278	271250	190545	7627	16218
Ankistrodesmus sp.	1542	386	1735	3277	1157
Chlorella sp.	9037	0	0	0	0
Crucigenia sp.	0	0	0	0	2024
Oocystis sp.	0	48799	35244	27111	35244
nannoflagellata	15619	11509	21373	7672	10961
TOTAL CHLOROPHYTA	26198	60693	58352	38060	49385
Cryptomonas sp.	51088	40871	86850	15327	0
Rhodomonas sp.	151494	27834	22267	13519	4771
TOTAL CRYPTOPHYTA	202582	68704	109117	28846	4771
Site N2 - 8 m					
Anabaena flos-aquae	7229	11447	0	20484	46992
Aphanizomen flos-aquae	0	615121	70976	189268	1395852
Chroococcus sp.	0	1566	0	1566	0
Gloeocapsa sp.	0	8193	20484	0	0
Gomphosphaeria sp.	0	0	0	0	2024
TOTAL CYANOBACTERIA	7229	636328	91459	211318	1444868

Table 30 continued

Taxon	24/05	10/06	20/06	04/07	18/07
Site N2 - 8 m (continued)					
Asterionella formosa	121455	134950	6748	0	0
Cyclotella sp. (medium)	52667	3398	13591	5097	1699
Cyclotella sp. (small)	0	10603	67331	0	0
Fragilaria sp.	105731	43702	222741	1410	11278
Navicula sp.	3735	0	3735	0	7470
TOTAL BACILLARIOPHYTA	283589	192654	314145	6507	20447
Ankistrodesmus sp.	771	0	193	4049	0
Chlorella sp.	21688	0	0	1807	0
Cosmarium sp.	386	0	0	0	0
Crucigenia sp.	2024	0	0	0	0
Oocystis sp.	2711	13555	13555	29822	8133
Scenedesmus sp.	8097	1350	0	0	675
nannoflagellata	7408	3065	9962	4087	3193
TOTAL CHLOROPHYTA	43085	17970	23710	39765	12001
Cryptomonas sp.	56197	10218	35762	5109	15327
Rhodomonas sp.	8748	2783	12724	13519	2783
TOTAL CRYPTOPHYTA	64945	13001	48486	18628	18110
Site N2 - 18 m					
Anabaena flos-aquae	11633	69796	40068	0	0
Aphanizomen flos-aquae	101514	50757	0	50757	101514
Chroococcus sp.	13442	0	10082	0	0
Gloeocapsa sp.	0	19776	0	0	0
Gomphosphaeria sp.	1086	0	0	0	0
TOTAL CYANOBACTERIA	127675	140329	50150	50757	101514
Asterionella formosa	57905	130286	14476	0	0
Cyclotella sp. (medium)	0	7290	0	0	3645
Cyclotella sp. (small)	268430	1137	0	0	0
Fragilaria sp.	39318	6049	142151	18147	0
Navicula sp.	8014	0	0	0	0
TOTAL BACILLARIOPHYTA	373667	144762	156627	18147	3645

Table 30 continued

Taxon	24/05	10/06	20/06	04/07	18/07
Site N2 -18 m (continued)					
Ankistrodesmus sp.	414	0	0	414	0
Chlorella sp.	38776	3878	0	0	0
Oocystis sp.	11633	23265	0	0	5816
nannoflagellata	4932	2740	3288	4110	822
TOTAL CHLOROPHYTA	55754	29883	3288	4524	6638
Cryptomonas sp.	0	10961	0	0	32882
Rhodomonas sp.	10237	5971	6824	6824	2559
TOTAL CRYPTOPHYTA	10237	16932	6824	6824	35441

Table 30 (continued)

Taxon	02/08	15/08	20/09	18/10
Site N2 - 3 m				
Anabaena flos-aquae	653666	200618	91574	4820
Aphanizomen flos-aquae	7334136	1111950	94634	236585
Chroococcus sp.	1566	9398	21929	7832
Gloeocapsa sp.	104466	0	0	13314
Gomphosphaeria sp.	70343	92610	54149	18218
Lyngbya sp.	0	0	37834	47293
TOTAL CYANOBACTERIA	8164177	1414576	300120	328062
Asterionella formosa	0	0	13495	0
Cyclotella sp. (medium)	3398	1699	1699	3398
Fragilaria sp.	2820	7049	1410	14098
Navicula sp.	0	0	3735	0
TOTAL BACILLARIOPHYTA	6217	8748	20339	17495
Ankistrodesmus sp.	771	386	964	578
Chlorella sp.	0	0	5422	0
Crucigenia sp.	2024	2024	0	0
Oocystis sp.	5422	10844	35244	13555
Scenedesmus sp.	0	0	675	0
nannoflagellata	62475	11235	13975	13153
TOTAL CHLOROPHYTA	70693	24489	56279	27286
Cryptomonas sp.	56197	25544	40871	35762
Rhodomonas sp.	21869	13519	7952	7157
TOTAL CRYPTOPHYTA	78066	39063	48823	42919
Site N2 - 8 m				
Anabaena flos-aquae	94586	51811	18074	16266
Aphanizomen flos-aquae	1206584	354878	0	0
Chroococcus sp.	0	9398	7832	7832
Gomphosphaeria sp.	12652	58703	23279	49594
Lyngbya sp.	9459	0	37834	85127
TOTAL CYANOBACTERIA	1323280	474791	87019	158820

Table 30 continued

Taxon	02/08	15/08	20/09	18/10
Site N2 - 8 m (continued)				
Asterionella formosa	0	0	6748	6748
Cyclotella sp. (medium)	0	1699	3398	0
Fragilaria sp.	5639	1410	9868	18327
TOTAL BACILLARIOPHYTA	5639	3109	20014	25074
Ankistrodesmus sp.	0	1735	193	193
Chlorella sp.	0	1807	1807	1807
Cosmarium sp.	0	386	0	0
Oocystis sp.	13555	18977	10844	29822
Scenedesmus sp.	0	0	675	0
Staurastrum sp.	0	0	96393	0
nannoflagellata	6258	2938	6641	7152
TOTAL CHLOROPHYTA	19814	25843	116554	38974
Cryptomonas sp.	5109	5109	35762	30653
Rhodomonas sp.	7952	8350	6362	9145
TOTAL CRYPTOPHYTA	13061	13459	42124	39798
Site N2 - 18 m				
Anabaena flos-aquae	62041	0	3878	11633
Aphanizomen flos-aquae	609086	304543	101514	0
Chroococcus sp.	0	0	6721	10082
Gomphosphaeria sp.	4343	5429	4343	8686
Lyngbya sp.	0	0	0	101463
TOTAL CYANOBACTERIA	675469	309971	116456	131863
Cyclotella sp. (medium)	3645	3645	0	3645
Fragilaria sp.	0	0	0	24196
TOTAL BACILLARIOPHYTA	3645	3645	0	27841
Ankistrodesmus sp.	414	0	0	0
Oocystis sp.	11633	0	0	0
nannoflagellata	5206	2192	3014	4932
TOTAL CHLOROPHYTA	17253	2192	3014	4932

Table 30 continued

Taxon	02/08	15/08	20/09	18/10
Site N2 - 18 m (continued)				
Cryptomonas sp.	0	0	10961	21921
Rhodomonas sp.	0	3412	5118	7678
TOTAL CRYPTOPHYTA	0	3412	16079	29599

Table 30 continued

Taxon	24/05	10/06	20/06	04/07	18/07
Site S3 - 3 m					
Anabaena flos-aquae	6627	39762	15664	311470	139168
Aphanizomen flos-aquae	354878	2886337	3028288	2176582	6813649
Chroococcus sp.	1566	1566	0	0	0
Gloeocapsa sp.	8193	28677	0	112660	6145
Gomphosphaeria sp.	0	0	0	506	15182
TOTAL CYANOBACTERIA	371264	2956343	3043952	2601218	6974143
Asterionella formosa	134950	141698	0	6748	0
Cyclotella sp. (medium)	18688	15290	10194	10194	0
Cyclotella sp. (small)	0	20676	34461	0	0
Fragilaria sp.	14098	111370	140975	1410	1410
Stephanodiscus sp.	11977	0	0	0	0
TOTAL BACILLARIOPHYTA	179713	289035	185629	18351	1410
Ankistrodesmus sp.	386	0	1350	3856	964
Chlorella sp.	0	1807	0	0	0
Oocystis sp.	0	0	29822	56932	13555
Scenedesmus sp.	5398	0	0	0	0
nannoflagellata	20551	6576	14797	3562	11235
TOTAL CHLOROPHYTA	26335	8384	45968	64350	25754
Cryptomonas sp.	0	25544	71524	35762	20435
Rhodomonas sp.	71572	20279	47317	9543	18291
TOTAL CRYPTOPHYTA	71572	45823	118841	45305	38726
Site S3 - 8 m					
Anabaena flos-aquae	3615	34340	10844	153024	33135
Aphanizomen flos-aquae	496829	615121	260244	260244	709755
Chroococcus sp.	0	0	0	10182	6266
Gloeocapsa sp.	4097	3073	0	25604	0
Gomphosphaeria sp.	0	0	0	7591	8097
TOTAL CYANOBACTERIA	504540	652534	271088	456645	757253

Table 30 continued

Taxon	24/05	10/06	20/06	04/07	18/07
Site S1 - 8 m (continued)					
Asterionella formosa	114708	371114	13495	0	0
Cyclotella sp. (medium)	11893	6796	16989	3398	13591
Cyclotella sp. (small)	0	19616	50896	0	0
Fragilaria sp.	81766	105731	279131	0	0
Stephanodiscus sp.	0	5988	0	0	0
TOTAL BACILLARIOPHYTA	208366	509245	36051	3398	13591
Ankistrodesmus sp.	578	193	193	0	193
Chlorella sp.	7229	3615	1807	0	0
Oocystis sp.	0	16266	16266	65065	8133
Scenedesmus sp.	2699	0	0	0	0
nannoflagellata	12517	7919	8174	1660	1022
TOTAL CHLOROPHYTA	23024	27993	26441	66726	9348
Cryptomonas sp.	10218	5109	35762	15327	0
Rhodomonas sp.	57655	16302	18291	4374	3181
TOTAL CRYPTOPHYTA	67873	21411	54052	19700	3181
Site S3 - 18 m					
Anabaena flos-aquae	0	0	0	0	3878
Aphanizomen flos-aquae	253786	50757	0	101514	50757
Chroococcus sp.	0	0	0	3361	0
Gomphosphaeria sp.	4343	1086	0	0	0
TOTAL CYANOBACTERIA	258129	51843	0	104875	54635
Asterionella formosa	28952	43429	57905	0	0
Cyclotella sp. (medium)	0	7290	0	65608	3645
Cyclotella sp. (small)	197910	40947	35260	0	0
Fragilaria sp.	15122	0	130053	0	0
Navicula sp.	0	8014	8014	0	16027
TOTAL BACILLARIOPHYTA	241985	99679	231231	65608	19672

Table 30 continued

Taxon	24/05	10/06	20/06	04/07	18/07
Site S1 - 18 m (continued)					
Ankistrodesmus sp.	414	1241	414	0	0
Chlorella sp.	11633	0	3878	0	0
Oocystis sp.	34898	5816	5816	0	5816
nannoflagellata	47678	1918	4658	1644	1644
TOTAL CHLOROPHYTA	94623	8975	14766	1644	7460
Rhodomonas sp.	1706	2559	1706	0	1706
TOTAL CRYPTOPHYTA	1706	2559	1706	0	1706

Table 30 continued

Taxon	02/08	15/08	20/09	18/10
Site S3 - 3 m				
Anabaena flos-aquae	392802	159049	49402	2410
Aphanizomen flos-aquae	7121209	828048	47317	23659
Chroococcus sp.	10965	9398	10965	0
Gloeocapsa sp.	32774	0	0	8193
Gomphosphaeria sp.	81982	117407	42509	27327
Lyngbya sp.	0	0	85127	28376
TOTAL CYANOBACTERIA	7639732	1113902	235320	89965
Cyclotella sp. (medium)	0	0	1699	5097
Fragilaria sp.	0	0	5639	0
Navicula sp.	7470	0	0	3735
Stephanodiscus sp.	0	0	0	5988
TOTAL BACILLARIOPHYTA	7470	0	7338	14820
Ankistrodesmus sp.	1542	386	771	193
Cosmarium sp.	0	386	0	0
Crucigenia sp.	2024	2024	0	0
Elakatrothrix sp.	0	0	2410	0
Oocystis sp.	5422	13555	10844	35244
Scenedesmus sp.	0	675	0	0
nannoflagellata	32334	13975	12605	3288
TOTAL CHLOROPHYTA	41322	31000	26630	38725
Cryptomonas sp.	15327	0	20435	40871
Rhodomonas sp.	25845	11929	8748	7555
TOTAL CRYPTOPHYTA	41172	11929	29183	48426
Site S3 - 8 m				
Anabaena flos-aquae	34943	66873	89164	0
Aphanizomen flos-aquae	591463	212927	141951	165610
Chroococcus sp.	1566	0	9398	12531
Gloeocapsa sp.	0	0	13314	0
Gomphosphaeria sp.	8097	17712	29858	16194

Table 30 continued

Taxon	02/08	15/08	20/09	18/10
Site S1 - 8 m (continued)				
Lyngbya sp.	0	0	75669	56751
TOTAL CYANOBACTERIA	636068	297512	359354	251086
Asterionella formosa	0	0	13495	13495
Cyclotella sp. (medium)	1699	0	0	1699
Fragilaria sp.	1410	0	4229	7049
Stephanodiscus sp.	0	0	0	5988
TOTAL BACILLARIOPHYTA	3109	0	17724	28231
Ankistrodesmus sp.	0	193	578	0
Crucigenia sp.	0	0	10121	0
Oocystis sp.	8133	13555	13555	10844
Scenedesmus sp.	0	0	675	0
Staurastrum sp.	0	0	0	96393
nannoflagellata	3704	1788	12261	3321
TOTAL CHLOROPHYTA	11837	15536	37191	110558
Cryptomonas sp.	15327	0	10218	10218
Rhodomonas sp.	2783	3579	17495	13122
TOTAL CRYPTOPHYTA	18110	3579	27713	23339
Site S3 - 18 m				
Anabaena flos-aquae	0	0	0	21973
Aphanizomen flos-aquae	101514	152271	101514	152271
Chroococcus sp.	0	0	0	6721
Gomphosphaeria sp.	6514	2171	8686	8686
Lyngbya sp.	0	0	0	20293
TOTAL CYANOBACTERIA	108029	154443	110200	209944
Asterionella formosa	0	0	14476	28952
Cyclotella sp. (medium)	10935	0	0	0
Cymbella sp.	0	0	4136	0
Fragilaria sp.	0	0	3024	3024

Table 30 continued

Taxon	02/08	15/08	20/09	18/10
Site S3 - 18 m (continued)				
Navicula sp.	8014	0	0	0
TOTAL BACILLARIOPHYTA	18948	0	21637	31977
Chlorella sp.	19388	0	3878	0
Oocystis sp.	1633	17449	0	5816
nannoflagellata	3288	4658	5754	3562
TOTAL CHLOROPHYTA	34309	22107	9632	9379
Cryptomonas sp.	10961	0	10961	0
Rhodomonas sp.	0	853	2559	853
TOTAL CRYPTOPHYTA	10961	853	13520	853

Table 31: Phytoplankton biovolumes ($\mu m^3 \cdot mL^{-1}$), 1989. The sum of the biovolumes in each group may not equal the total due to rounding errors.

Taxon	17/05	30/05	16/06	28/06	18/07	25/07
Site N2 - 3 m						
Anabaena flos-aquae	0	0	8434	72295	93983	606675
Aphanizomenon flos-aquae	0	0	165610	141951	283902	425853
Chroococcus sp.	0	0	1566	6266	0	0
Gloecapsa sp.	0	0	0	0	49161	29701
Gomphosphaeria sp.	0	0	1215	0	0	0
TOTAL CYANOBACTERIA	0	0	176825	220511	427046	1062229
Asterionella formosa	665905	1708190	6748	0	0	0
Cyclotella sp. (medium)	0	7290	0	6796	20387	6796
Cyclotella sp. (small)	1594656	59146	6362	0	0	0
Fragilaria sp.	151224	145176	29605	0	4229	1410
Navicula sp.	64109	32054	0	0	0	0
Stephanodiscus sp.	25695	0	0	0	0	0
TOTAL BACILLARIOPHYTA	2501589	1951856	42714	6796	24616	8205
Ankistrodesmus sp.	0	0	14652	771	1157	578
Chlorella sp.	0	0	0	0	1807	0
Crucigenia sp.	0	0	0	4049	3036	0
Oocystis sp.	0	11633	29822	138264	16266	8133
nannoflagellata	53159	83300	15582	4658	7672	27401
TOTAL CHLOROPHYTA	53159	94933	60055	147742	29939	36113
Cryptomonas sp.	0	43842	71524	10218	0	0
Rhodomonas sp.	11943	5118	21074	14314	9543	6760
TOTAL CRYPTOPHYTA	11943	48961	92598	24532	9543	6760
Site N2 - 5.5 m						
Anabaena flos-aquae	0	0	7832	36147	96996	567515
Aphanizomenon flos-aquae	0	101514	165610	260244	686097	1561461
Chroococcus sp.	0	0	1566	6266	0	7832
Gloecapsa sp.	0	0	0	0	40967	26629
Gomphosphaeria sp.	26057	19543	11791	0	0	0

Table 31 continued

Taxon	17/05	30/05	16/06	28/06	18/07	25/07
Site N2 - 5.5 m (continued)						
Lyngbya sp.	0	40585	0	0	0	0
TOTAL CYANOBACTERIA	26057	161642	186799	302657	824059	2163437
Asterionella formosa	86857	955429	74223	0	0	0
Cyclotella sp. (large)	0	0	26315	0	0	0
Cyclotella sp. (medium)	0	0	0	18688	45871	23785
Cyclotella sp. (small)	1487738	106917	0	0	0	0
Cymbella sp.	0	0	1928	0	1928	0
Fragilaria sp.	151224	435527	0	0	0	0
Navicula sp.	48082	0	0	0	0	0
Stephanodiscus sp.	77086	0	0	0	0	0
TOTAL BACILLARIOPHYTA	1850987	1497872	102466	18688	47799	23785
Ankistrodesmus sp.	0	0	4049	2699	1350	1735
Chlorella sp.	0	0	7229	0	0	0
Cosmarium sp.	0	0	1157	0	0	0
Crucigenia sp.	0	0	2024	0	0	0
Oocystis sp.	0	0	29822	105731	43377	37955
nannoflagellata	35074	47130	11750	5754	6302	10687
TOTAL CHLOROPHYTA	35074	47130	56031	114185	51029	50376
Cryptomonas sp.	0	43842	122612	5109	5109	35762
Rhodomonas sp.	1706	6824	7157	23062	6362	5567
TOTAL CRYPTOPHYTA	1706	50667	129769	28171	11471	41329
Site N2 - 8 m						
Anabaena flos-aquae	0	33605	32433	6025	9639	65065
Aphanizomenon flos-aquae	0	101514	141951	0	94634	118293
Chroococcus sp.	0	0	0	12531	0	0
Gomphosphaeria sp.	1086	6514	8502	0	6073	8097
TOTAL CYANOBACTERIA	1086	141634	182886	18556	110346	191455

Table 31 continued

Taxon	17/05	30/05	16/06	28/06	18/07	25/07
Site N2 - 8 m (continued)						
Asterionella formosa	289524	608000	47233	13495	0	0
Cyclotella sp. (large)	0	0	13158	0	0	0
Cyclotella sp. (medium)	0	14580	0	5097	16989	20387
Cyclotella sp. (small)	1458165	102367	0	0	0	0
Fragilaria sp.	66539	96784	2820	0	11278	0
Navicula sp.	16027	48082	3735	0	0	0
Stephanodiscus sp.	102781	25695	17965	0	0	0
TOTAL BACILLARIOPHYTA	1933036	895507	84910	18592	28267	20387
Ankistrodesmus sp.	0	827	1542	1157	386	771
Oocystis sp.	0	0	10844	48799	40666	8133
nannoflagellata	23565	35622	9962	5480	3014	7124
TOTAL CHLOROPHYTA	23565	36449	22349	55436	44066	16029
Cryptomonas sp.	0	109605	86850	5109	0	5109
Rhodomonas sp.	11943	6824	2386	7952	4771	1988
TOTAL CRYPTOPHYTA	11943	116430	89236	13061	4771	7097
Site N2 - 10.5 m						
Aphanizomenon flos-aquae	0	0	0	0	0	101514
Chroococcus sp.	0	0	3133	0	0	0
Gomphosphaeria sp.	0	0	0	2714	0	0
TOTAL CYANOBACTERIA	0	0	6266	5429	0	203028
Asterionella formosa	0	723810	80970	28952	14476	0
Cyclotella sp. (medium)	0	0	0	0	0	3645
Cyclotella sp. (small)	1064620	232033	9013	0	0	0
Fragilaria sp.	18147	235910	181858	0	0	0
Navicula sp.	32054	0	0	0	0	0
Stephanodiscus sp.	25695	51390	71861	0	0	0
TOTAL BACILLARIOPHYTA	1140517	1243143	343702	28952	14476	3645

Table 31 continued

Taxon	17/05	30/05	16/06	28/06	18/07	25/07
Site N2 - 10.5 m (continued)						
Ankistrodesmus sp.	0	0	0	0	414	414
Chlorella sp.	0	775510	0	0	19388	0
Oocystis sp.	0	0	0	46531	23265	23265
nannoflagellata	18085	51515	5620	1918	4110	6576
TOTAL CHLOROPHYTA	18085	827025	5620	48449	47177	30255
Cryptomonas sp.	0	131527	25544	10961	10961	0
Rhodomonas sp.	6824	10237	5567	853	3412	6824
TOTAL CRYPTOPHYTA	6824	141763	31111	11814	14373	6824
Site N2 - 13 m						
Anabaena flos-aquae	0	677279	0	0	0	19388
Aphanizomenon flos-aquae	0	101514	23659	0	50757	0
Chroococcus sp.	0	0	3133	0	0	0
Gomphosphaeria sp.	1086	0	0	0	0	0
Oscillatoria sp.	0	0	10442	0	0	0
TOTAL CYANOBACTERIA	1086	778793	37234	0	50757	19388
Asterionella formosa	0	694857	74223	28952	0	0
Cyclotella sp. (medium)	0	14580	27183	3645	10935	3645
Cyclotella sp. (small)	1126040	227483	0	0	0	0
Cymbella sp.	0	0	1928	0	0	0
Fragilaria sp.	60490	84686	60619	3024	0	0
Navicula sp.	0	16027	0	0	0	0
Stephanodiscus sp.	51390	25695	41919	0	0	0
TOTAL BACILLARIOPHYTA	1237920	1063328	205872	35622	10935	3645
Ankistrodesmus sp.	0	0	964	827	827	0
Chlorella sp.	0	54286	23496	0	0	0
Oocystis sp.	0	0	5422	5816	11633	58163
nannoflagellata	34526	15345	10218	3836	3014	5480
TOTAL CHLOROPHYTA	34526	69630	40100	10480	15474	63644

Table 31 continued

Taxon	17/05	30/05	16/06	28/06	18/07	25/07
Site N2 - 13 m (continued)						
Cryptomonas sp.	0	65763	10218	21921	0	0
Rhodomonas sp.	8531	8531	6760	853	1706	2559
TOTAL CRYPTOPHYTA	8531	74294	16977	22774	1706	2559
Site N2 - 18 m						
Anabaena flos-aquae	0	0	14459	0	19388	0
Aphanizomenon flos-aquae	0	0	0	0	101514	0
Gomphosphaeria sp.	19109	0	607	0	0	0
Lyngbya sp.	0	0	0	0	20293	0
TOTAL CYANOBACTERIA	19109	0	15066	0	141194	0
Asterionella formosa	57905	463238	87718	57905	28952	0
Cyclotella sp. (medium)	0	7290	0	0	7290	7290
Cyclotella sp. (small)	846237	268430	36581	0	0	0
Fragilaria sp.	30245	114931	25376	0	3024	0
Navicula sp.	0	16027	3735	0	0	0
Stephanodiscus sp.	0	0	41919	0	0	0
TOTAL BACILLARIOPHYTA	934386	869916	195329	57905	39267	7290
Ankistrodesmus sp.	0	0	1157	0	0	0
Chlorella sp.	0	77551	0	0	0	0
Oocystis sp.	0	0	0	40714	11633	11633
Scenedesmus sp.	0	0	2024	0	0	0
nannoflagellata	38362	18085	9451	822	5480	1644
TOTAL CHLOROPHYTA	38362	95636	12632	41536	17113	13277
Cryptomonas sp.	0	21921	5109	0	0	0
Rhodomonas sp.	3412	1706	2783	0	0	2559
TOTAL CRYPTOPHYTA	3412	23627	7892	0	0	2559

Table 31 continued

Taxon	09/08	22/08	05/09	18/09	02/10	16/10
Site N2 - 3 m						
Anabaena flos-aquae	806690	1383845	1206120	3356290	295204	407864
Aphanizomenon flos-aquae	946340	1230242	449512	402195	260244	757072
Chroococcus sp.	18797	23496	43859	36027	34461	44642
Gloecapsa sp.	8193	11266	0	0	0	0
Gomphosphaeria sp.	11133	30364	1012	3795	4049	9919
Lyngbya sp.	0	0	28376	47293	37834	122962
TOTAL CYANOBACTERIA	1791154	2679212	1728878	3845600	631791	1342458
Asterionella formosa	0	13495	0	0	0	0
Cyclotella sp. (medium)	0	0	0	1699	3398	3398
Fragilaria sp.	1410	0	0	0	4229	7049
Navicula sp.	3735	0	7470	0	0	11206
Stephanodiscus sp.	0	0	0	0	0	5988
TOTAL BACILLARIOPHYTA	5145	13495	7470	1699	7627	27641
Ankistrodesmus sp.	771	193	386	386	386	386
Chlorella sp.	0	0	0	5422	1807	10844
Cosmarium sp.	0	0	0	771	0	0
Crucigenia sp.	4049	0	4049	0	0	0
Elakatothrix sp.	3615	0	0	0	0	0
Oocystis sp.	18977	21688	0	8133	0	21688
nannoflagellata	42746	20003	11783	13411	13411	25757
TOTAL CHLOROPHYTA	70158	41884	16217	28123	15604	58676
Cryptomonas sp.	15327	10218	25544	51088	25544	15327
Rhodomonas sp.	21074	7952	13519	21074	20676	25448
TOTAL CRYPTOPHYTA	36400	18170	39063	72162	46221	40774
Site N2 - 5.5 m						
Anabaena flos-aquae	232549	470519	600048	1283837	145795	62656
Aphanizomenon flos-aquae	1040974	1230242	544146	449512	520487	686097
Chroococcus sp.	14098	9398	37593	4699	16447	0
Gloecapsa sp.	0	4097	0	0	0	15363

Table 31 continued

Taxon	09/08	22/08	05/09	18/09	02/10	16/10
Site N2 - 5.5 m (continued)						
Gomphosphaeria sp.	11639	11133	9615	22317	2024	2024
Lyngbya sp.	0	0	28376	18917	28376	75669
TOTAL CYANOBACTERIA	1299260	1725390	1219777	1779282	713129	841808
Cyclotella sp. (medium)	0	0	0	1699	3398	0
Fragilaria sp.	1410	0	4229	2820	4229	1409075
Stephanodiscus sp.	0	0	0	0	0	5988
TOTAL BACILLARIOPHYTA	1410	0	4229	4518	7627	1415063
Ankistrodesmus sp.	386	193	193	578	193	578
Chlorella sp.	0	1807	0	19881	1807	5422
Cosmarium sp.	0	0	0	1928	0	0
Elakatothrix sp.	6025	0	2410	0	0	0
Oocystis sp	16266	0	5422	10844	5422	2711
nannoflagellata	8494	14797	12057	14688	12133	19455
TOTAL CHLOROPHYTA	31171	16797	20081	47919	19556	28166
Cryptomonas sp.	30653	10218	5109	20435	35762	10218
Rhodomonas sp.	5534	3976	9543	27436	13917	23460
TOTAL CRYPTOPHYTA	36220	14194	14652	47871	49679	33677
Site N2 - 8 m						
Anabaena flos-aquae	71692	80127	69885	345208	371114	131938
Aphanizomenon flos-aquae	165610	189268	165610	212927	378536	449512
Chroococcus sp.	3133	0	9398	25062	0	0
Gomphosphaeria sp.	2530	4049	1518	17004	5061	0
Lyngbya sp.	0	0	0	0	113503	47293
Oscillatoria sp.	0	0	0	1097	0	0
TOTAL CYANOBACTERIA	242965	273443	246411	601298	868213	628743
Cyclotella sp. (medium)	5097	0	0	0	1699	5097
Fragilaria sp.	2820	0	0	1410	4229	5639
TOTAL BACILLARIOPHYTA	7916	0	0	1410	5928	10736

Table 31 continued

Taxon	09/08	22/08	05/09	18/09	02/10	16/10
Site N2 - 8 m (continued)						
Ankistrodesmus sp.	193	771	193	578	0	386
Chlorella sp.	0	0	0	7229	0	1807
Cosmarium sp.	0	0	0	386	0	0
Oocystis sp.	13555	0	8133	18977	0	0
nannoflagellata	9864	8494	5480	13922	13922	17263
TOTAL CHLOROPHYTA	23613	9266	13806	41092	13922	19456
Cryptomonas sp.	0	5109	0	5109	20435	0
Rhodomonas sp.	4771	795	6760	13519	13122	11531
TOTAL CRYPTOPHYTA	4771	5904	6760	18628	33557	11531
Site N2 - 10.5 m						
Anabaena flos-aquae	0	68503	74966	34340	264966	109864
Aphanizomenon flos-aquae	0	101514	101514	23659	507571	203029
Chroococcus sp.	0	6721	23524	17230	6721	33605
Gloecapsa sp.	0	0	0	0	0	28565
Gomphosphaeria sp.	0	0	2171	7287	0	0
Lyngbya sp.	0	0	40585	18917	60878	40585
TOTAL CYANOBACTERIA	0	353477	485521	202867	1680272	831295
Cyclotella sp. (medium)	14580	0	0	1699	7290	0
Fragilaria sp.	0	0	0	1410	6049	12098
Navicula sp.	0	0	0	0	0	0
TOTAL BACILLARIOPHYTA	14580	0	0	3109	13339	12098
Ankistrodesmus sp.	0	0	0	193	0	0
Chlorella sp.	0	0	0	16266	7755	3878
Cosmarium sp.	0	0	827	386	0	0
Oocystis sp.	11633	17449	5816	5422	0	11633
nannoflagellata	4110	3562	3836	9707	23017	14797
TOTAL CHLOROPHYTA	15743	21011	10480	31974	30772	30307

Table 31 continued

Taxon	09/08	22/08	05/09	18/09	02/10	16/10
Site N2 - 10.5 m (continued)						
Cryptomonas sp.	0	0	0	0	21921	10961
Rhodomonas sp.	2559	5971	2559	5964	12796	10237
TOTAL CRYPTOPHYTA	2559	5971	2559	5964	34717	21197
Site N2 - 13 m						
Anabaena flos-aquae	0	43946	2585	84344	133129	56871
Aphanizomenon flos-aquae	253786	50757	50757	0	659843	355300
Chroococcus sp.	0	0	0	9398	0	0
Gomphosphaeria sp.	0	0	0	5263	0	6514
Lyngbya sp.	0	0	0	0	60878	121755
TOTAL CYANOBACTERIA	253786	94703	53342	99005	853850	540440
Cyclotella sp. (medium)	3645	3645	0	1699	0	7290
Fragilaria sp.	6049	6049	0	0	6049	6049
Stephanodiscus sp.	0	0	0	0	12848	0
TOTAL BACILLARIOPHYTA	9694	9694	0	1699	18897	13339
Ankistrodesmus sp.	0	0	0	578	0	0
Chlorella sp.	0	0	0	3615	3878	3878
Cosmarium sp.	0	0	0	386	0	0
Oocystis sp.	23265	0	5816	8133	5816	0
nannoflagellata	5754	4110	4932	8813	19181	13427
TOTAL CHLOROPHYTA	29020	4110	10749	21525	28875	17304
Cryptomonas sp.	0	0	0	0	21921	0
Rhodomonas sp.	5917	3412	6824	6362	12796	20473
TOTAL CRYPTOPHYTA	5917	3412	6824	6362	34717	20473
Site N2 - 18 m						
Anabaena flos-aquae	21973	52993	15510	237823	34898	76259
Aphanizomenon flos-aquae	101514	0	203029	304543	0	355300
Chroococcus sp.	0	0	6721	40327	20163	0

Table 31 continued

Taxon	09/08	22/08	05/09	18/09	02/10	16/10
Site N2 - 18 m (continued)						
Gloecapsa sp.	0	17578	0	0	0	0
Lyngbya sp.	0	0	20293	0	20293	60878
Oscillatoria sp.	0	0	0	2273	0	0
TOTAL CYANOBACTERIA	123487	70571	245552	584965	75354	492436
Asterionella formosa	0	0	0	0	0	14476
Cyclotella sp. (medium)	3645	0	0	7290	0	7290
Fragilaria sp.	3024	0	0	0	9073	6049
TOTAL BACILLARIOPHYTA	19517	0	0	7290	9073	27815
Ankistrodesmus sp.	0	0	0	0	0	414
Chlorella sp.	0	0	0	7755	0	7755
Cosmarium sp.	0	0	0	1654	0	0
Oocystis sp.	5816	5816	5816	23265	0	5816
nannoflagellata	2740	3288	2466	15893	10961	9042
TOTAL CHLOROPHYTA	8556	9104	8282	48568	10961	23027
Rhodomonas sp.	853	3412	853	8531	0	13649
TOTAL CRYPTOPHYTA	853	3412	853	8531	0	13649

Table 31 continued

Taxon	17/05	30/05	16/06	28/06	18/07	25/07
Site S1 - 3 m						
Anabaena flos-aquae	0	0	657883	58438	445818	717527
Aphanizomenon flos-aquae	101514	203029	70976	165610	378536	473170
Chroococcus sp.	0	0	3133	0	3133	3133
Gloecapsa sp.	0	0	0	26629	0	8193
Gomphosphaeria sp.	0	0	1771	0	0	506
Lyngbya sp.	0	0	0	0	9459	0
TOTAL CYANOBACTERIA	101514	203029	733763	250676	836946	1202529
Asterionella formosa	636952	897524	20243	0	0	13495
Cyclotella sp. (large)	0	0	13158	0	0	0
Cyclotella sp. (medium)	0	14580	0	16989	30581	5097
Cyclotella sp. (small)	1317126	122841	0	0	0	0
Fragilaria sp.	127029	175420	5639	0	42293	1410
Navicula sp.	64109	32054	0	0	0	0
Stephanodiscus sp.	0	25695	0	0	0	0
TOTAL BACILLARIOPHYTA	2145216	1268114	39039	16989	72873	20002
Ankistrodesmus sp.	0	0	20821	578	1157	1350
Chlorella sp.	0	0	7229	0	0	0
Crucigenia sp.	0	0	0	2024	2024	5567
Oocystis sp.	0	0	10844	51510	16266	18977
nannoflagellata	86040	68503	10729	8220	10413	8768
TOTAL CHLOROPHYTA	86040	68503	49623	62333	29860	34662
Cryptomonas sp.	65763	87684	40871	0	10218	0
Rhodomonas sp.	27298	23886	31015	7157	22267	6760
TOTAL CRYPTOPHYTA	93061	111570	71885	7157	32484	6760
Site S1 - 5.5 m						
Anabaena flos-aquae	0	54286	41570	4820	68680	75307
Aphanizomenon flos-aquae	304543	0	23659	23659	331219	828048
Chroococcus sp.	6721	0	4699	3133	1566	0
Gloecapsa sp.	0	0	0	0	0	31750

Table 31 continued

Taxon	17/05	30/05	16/06	28/06	18/07	25/07
Site S1 - 5.5 m (continued)						
Gomphosphaeria sp.	0	0	3087	1012	759	2024
TOTAL CYANOBACTERIA	311264	54286	73014	32623	402225	937128
Asterionella formosa	434286	781714	114708	0	0	0
Cyclotella sp. (large)	0	0	26315	0	0	0
Cyclotella sp. (medium)	0	0	0	5097	30581	13591
Cyclotella sp. (small)	1428593	116016	0	0	0	0
Fragilaria sp.	157273	114931	0	0	0	0
Stephanodiscus sp.	25695	77086	0	0	0	0
TOTAL BACILLARIOPHYTA	2045847	1089747	141023	5097	30581	13591
Ankistrodesmus sp.	0	0	6362	4049	4820	3470
Cosmarium sp.	0	0	386	0	0	0
Oocystis sp.	0	0	5422	62354	56932	21688
nannoflagellata	48226	46582	17753	7398	3014	7398
TOTAL CHLOROPHYTA	48226	46582	29923	73801	64766	32557
Cryptomonas sp.	0	109605	97068	10218	15327	20435
Rhodomonas sp.	15355	13649	7555	17893	15507	2386
TOTAL CRYPTOPHYTA	15355	123254	104623	28111	30834	22821
Site S1 - 8 m						
Anabaena flos-aquae	0	10340	9639	0	150614	51209
Aphanizomenon flos-aquae	0	0	0	23659	23659	567804
Chroococcus sp.	0	0	0	1566	0	0
Gomphosphaeria sp.	0	0	8097	0	0	0
TOTAL CYANOBACTERIA	0	10340	17736	25225	174273	619013
Asterionella formosa	463238	1071238	40485	0	6748	6748
Cyclotella sp. (medium)	0	7290	0	1699	23785	6796
Cyclotella sp. (small)	2086019	195635	13254	0	0	0
Fragilaria sp.	157273	248008	39473	0	0	0
Navicula sp.	16027	32054	0	0	0	0

Table 31 continued

Taxon	17/05	30/05	16/06	28/06	18/07	25/07
Site S1 - 8 m (continued)						
Stephanodiscus sp.	25695	0	0	0	0	0
TOTAL BACILLARIOPHYTA	2748253	1554226	93212	1699	30533	13543
Ankistrodesmus sp.	0	1654	1350	1928	2313	964
Chlorella sp.	0	7755	3615	0	0	0
Oocystis sp.	0	0	13555	51510	10844	21688
Scenedesmus sp.	0	0	2699	0	0	0
nannoflagellata	30141	42746	15327	3836	5754	4932
TOTAL CHLOROPHYTA	30141	52156	36545	57274	18912	27585
Cryptomonas sp.	65763	109605	117503	30653	5109	10218
Rhodomonas sp.	17061	18767	1590	1193	1590	2386
TOTAL CRYPTOPHYTA	82824	128373	119094	31846	6699	12603
Site S1 - 10.5 m						
Anabaena flos-aquae	0	0	5422	0	0	7755
Aphanizomenon flos-aquae	0	203029	0	0	0	101514
Chroococcus sp.	0	0	0	3361	0	0
Gomphosphaeria sp.	0	0	1417	0	0	0
TOTAL CYANOBACTERIA	0	203029	6839	3361	0	109269
Asterionella formosa	144762	897524	87718	43429	0	0
Cyclotella sp. (medium)	0	7290	0	7290	18224	0
Cyclotella sp. (small)	934955	184261	118756	0	0	0
Cymbella sp.	0	165442	0	0	0	0
Fragilaria sp.	42343	0	101502	0	0	0
Navicula sp.	16027	0	7470	0	0	0
Stephanodiscus sp.	0	25695	35931	0	0	0
TOTAL BACILLARIOPHYTA	1138087	1280212	351377	50718	18224	0
Ankistrodesmus sp.	0	827	0	0	414	827
Chlorella sp.	0	31020	0	0	0	0

Table 31 continued

Taxon	17/05	30/05	16/06	28/06	18/07	25/07
Site S1 - 10.5 m (continued)						
Oocystis sp.	0	0	10844	17449	34898	5816
nannoflagellata	24113	42746	12133	3836	4110	5754
TOTAL CHLOROPHYTA	24113	74594	22978	21285	39422	12398
Cryptomonas sp.	21921	109605	0	0	0	0
Rhodomonas sp.	6824	1706	2386	2559	853	853
TOTAL CRYPTOPHYTA	28746	111312	2386	2559	853	853
Site S1 - 13 m						
Aphanizomenon flos-aquae	0	0	23659	0	0	0
Gomphosphaeria sp.	1086	4343	5263	0	0	2171
TOTAL CYANOBACTERIA	1086	4343	28922	0	0	2171
Asterionella formosa	115810	810667	67475	0	14476	28952
Cyclotella sp. (medium)	3054424	0	0	18224	21869	14580
Cyclotella sp. (small)	0	218384	41353	0	0	0
Cymbella sp.	8272	0	0	0	0	12408
Fragilaria sp.	66539	235910	59210	0	6049	30245
Navicula sp.	0	48082	3735	0	0	0
Stephanodiscus sp.	0	51390	41919	0	0	0
TOTAL BACILLARIOPHYTA	3245044	1364433	213692	18224	42395	86185
Ankistrodesmus sp.	0	0	0	414	414	1241
Chlorella sp.	0	31020	0	0	0	23265
Oocystis sp.	0	0	5422	23265	46531	29082
nannoflagellata	21921	21921	14305	2466	3014	4932
TOTAL CHLOROPHYTA	21921	52941	19727	26145	49958	58520
Cryptomonas sp.	0	65763	5109	0	0	10961
Rhodomonas sp.	1706	0	2386	2559	0	2559
TOTAL CRYPTOPHYTA	1706	65763	7495	2559	0	13520

Table 31 continued

Taxon	17/05	30/05	16/06	28/06	18/07	25/07
Site S1 - 18 m						
Anabaena flos-aquae	0	0	10844	91769	0	0
Aphanizomenon flos-aquae	0	0	0	50757	0	0
Chroococcus sp.	0	0	0	3361	0	0
Gomphosphaeria sp.	2389	0	0	0	0	0
TOTAL CYANOBACTERIA	2389	0	10844	145886	0	0
Asterionella formosa	173714	289524	121455	0	0	0
Cyclotella sp. (medium)	0	0	0	3645	10935	14580
Cyclotella sp. (small)	527761	311652	47715	0	0	0
Fragilaria sp.	6049	42343	47932	0	0	0
Navicula sp.	0	32054	3735	0	0	0
Stephanodiscus sp.	0	25695	71861	0	0	0
TOTAL BACILLARIOPHYTA	707524	701268	292698	3645	10935	14580
Ankistrodesmus sp.	0	0	386	0	0	0
Chlorella sp.	0	15510	0	0	0	0
Oocystis sp.	0	0	0	5816	11633	5816
Scenedesmus sp.	0	0	1350	0	0	0
nannoflagellata	20825	12057	7025	2740	2740	548
TOTAL CHLOROPHYTA	20825	27567	8760	8556	14373	6364
Cryptomonas sp.	43842	21921	5109	10961	0	10961
Rhodomonas sp.	0	1706	398	2559	0	0
TOTAL CRYPTOPHYTA	43842	23627	5506	13520	0	10961

Table 31 continued

Taxon	09/08	22/08	05/09	18/09	02/10	16/10
Site S1 - 3 m						
Anabaena flos-aquae	1327213	727769	1185636	1999556	793436	63860
Aphanizomenon flos-aquae	804389	1111949	283902	331219	875365	189268
Chroococcus sp.	32894	15664	34461	61089	15664	0
Gloecapsa sp.	0	16387	0	0	0	0
Gomphosphaeria sp.	10121	29352	24038	8097	4049	0
Lyngbya sp.	0	28376	9459	9459	104044	9459
TOTAL CYANOBACTERIA	2174617	1929496	1537495	2409420	1792558	262587
Asterionella formosa	0	0	20243	0	0	0
Cyclotella sp. (medium)	0	0	0	0	8495	5097
Fragilaria sp.	0	4229	7049	4229	25376	1410
Navicula	0	0	0	0	0	3735
TOTAL CYANOBACTERIA	0	4229	27291	4229	33870	10242
Ankistrodesmus sp.	386	386	0	193	193	0
Chlorella sp.	0	1807	0	0	3615	0
Crucigenia sp.	0	5061	4049	12146	0	0
Oocystis sp.	43377	16266	2711	0	2711	2711
nannoflagellata	24661	11509	16989	9707	14560	6028
TOTAL CHLOROPHYTA	164817	35028	23748	22045	21079	8739
Cryptomonas sp.	45980	0	25544	66415	30653	20435
Rhodomonas sp.	5964	6760	14314	17495	19881	7952
TOTAL CRYPTOPHYTA	51944	6760	39859	83910	50534	28388
Site S1 - 5.5 m						
Anabaena flos-aquae	651256	1318176	765723	3180372	504859	42774
Aphanizomenon flos-aquae	1159266	1159266	544146	307561	1064632	307561
Chroococcus sp.	1566	20363	65788	42293	10965	10965
Gloecapsa sp.	20484	0	30725	0	0	0
Gomphosphaeria sp.	9615	18208	3289	0	4049	0
Lyngbya sp.	0	9459	0	18917	56751	56751
TOTAL CYANOBACTERIA	1842188	2525472	1409672	3549142	1641256	418051

Table 31 continued

Taxon	09/08	22/08	05/09	18/09	02/10	16/10
Site S1 - 5.5 m (continued)						
Cyclotella sp. (medium)	0	1699	1699	1699	1699	3398
Fragilaria sp.	0	2820	0	4229	1410	1410
TOTAL BACILLARIOPHYTA	0	4518	1699	5928	3109	4808
Ankistrodesmus sp.	771	386	964	193	0	193
Chlorella sp.	0	0	0	0	0	3615
Cosmarium sp.	0	386	0	0	0	0
Crucigenia sp.	0	4049	17206	0	0	0
Oocystis sp.	16266	8133	10844	5422	0	0
Staurastrum sp.	48197	0	0	0	0	48197
nannoflagellata	9042	0	12331	14177	13538	5206
TOTAL CHLOROPHYTA	74277	12953	41345	19792	13538	57210
Cryptomonas sp.	25544	5109	25544	45980	15327	0
Rhodomonas sp.	4374	0	4374	27436	13519	11929
TOTAL CRYPTOPHYTA	29918	5109	29918	73415	28846	11929
Site S1 - 8 m						
Anabaena flos-aquae	46992	367499	63258	546429	375933	12652
Aphanizomenon flos-aquae	118293	141951	94634	473170	378536	0
Chroococcus sp.	1566	4699	10965	46992	17230	0
Gloecapsa sp.	0	0	16387	0	0	0
Gomphosphaeria sp.	4808	6073	3289	708	3036	2024
Lyngbya sp.	0	0	0	28376	56751	28376
TOTAL CYANOBACTERIA	171658	520222	188533	1095675	831488	43052
Asterionella formosa	13495	0	0	6748	6748	6748
Cyclotella sp. (medium)	11893	1699	0	0	1699	11893
Fragilaria sp.	0	1410	2820	2820	11278	0
Navicula sp.	0	3735	3735	0	0	0
TOTAL BACILLARIOPHYTA	25388	6844	6555	9567	19724	18640

Table 31 continued

Taxon	09/08	22/08	05/09	18/09	02/10	16/10
Site S1 - 8 m (continued)						
Ankistrodesmus sp.	771	386	193	0	193	0
Chlorella sp.	7229	0	0	1807	0	1807
Crucigenia sp.	4049	13158	0	0	0	0
Oocystis sp.	37955	21688	5422	0	2711	0
Staurastrum sp.	48197	0	0	0	96393	0
nannoflagellata	8494	4384	8768	14943	13922	7946
TOTAL CHLOROPHYTA	106695	39616	14383	16751	113219	9754
Cryptomonas sp.	5109	0	10218	40871	30653	10218
Rhodomonas sp.	3579	1193	3181	14712	19086	3181
TOTAL CRYPTOPHYTA	8687	1193	13399	55583	49739	13399
Site S1 - 10.5 m						
Anabaena flos-aquae	46531	96939	23265	80136	250748	49116
Aphanizomenon flos-aquae	101514	203029	0	101514	659843	507571
Chroococcus sp.	0	3361	13442	40327	0	0
Gloecapsa sp.	0	8789	0	0	0	0
Lyngbya sp.	0	0	0	0	81170	101463
TOTAL CYANOBACTERIA	148045	312117	36707	221977	991761	658150
Asterionella formosa	14476	0	0	0	0	0
Cyclotella sp. (medium)	0	0	3645	0	0	3645
Fragilaria sp.	0	6049	0	0	3024	6049
TOTAL BACILLARIOPHYTA	14476	6049	3645	0	3024	9694
Ankistrodesmus sp.	0	827	0	0	0	0
Chlorella	0	0	0	0	0	7755
Crucigenia sp.	0	8686	0	0	0	0
Oocystis sp.	0	11633	0	0	0	0
Staurastrum sp.	0	206803	0	0	0	0
nannoflagellata	2740	4658	0	0	0	0
TOTAL CHLOROPHYTA	2740	232607	0	0	0	7755

Table 31 continued

Taxon	09/08	22/08	05/09	18/09	02/10	16/10
Site S1 - 10.5 m (continued)						
Cryptomonas sp.	0	10961	10961	0	21921	10961
Rhodomonas sp.	3412	853	4265	0	11943	9384
TOTAL CRYPTOPHYTA	3412	11814	15226	0	33864	20344
Site S1 - 13 m						
Anabaena flos-aquae	0	31020	38776	90476	264966	27142
Aphanizomenon flos-aquae	50757	101514	101514	101514	456814	35530
Chroococcus sp.	0	0	1682	20163	0	0
Lyngbya sp.	0	0	0	40585	101463	223217
TOTAL CYANOBACTERIA	50757	132535	141972	252739	823243	285889
Asterionella formosa	0	0	14476	0	0	0
Cyclotella sp. (medium)	0	3645	0	0	3645	0
Fragilaria sp.	0	0	0	6049	6049	6049
Navicula sp.	0	8014	0	0	0	0
TOTAL BACILLARIOPHYTA	0	11659	14476	6049	9694	6049
Ankistrodesmus sp.	0	414	0	0	414	0
Chlorella sp.	0	15510	0	0	7755	11633
Cosmarium sp.	0	1654	0	3309	0	0
Crucigenia sp.	0	11943	0	0	0	0
Oocystis sp.	5816	11633	17449	11633	0	0
nannoflagellata	4658	3836	10961	13701	19729	7398
TOTAL CHLOROPHYTA	10475	44990	28410	28642	27898	19031
Cryptomonas sp.	0	10961	0	21921	21921	0
Rhodomonas sp.	0	1706	3412	1706	5118	2559
TOTAL CRYPTOPHYTA	0	12667	3412	23627	27039	2559
Site S1 - 18 m						
Anabaena flos-aquae	98231	0	45238	0	0	0
Aphanizomenon flos-aquae	0	50757	50757	101514	50757	253786

Table 31 continued

Taxon	09/08	22/08	05/09	18/09	02/10	16/10
Site S1 - 18 m (continued)						
Lyngbya sp.	0	0	0	0	0	40585
TOTAL CYANOBACTERIA	98231	50757	95995	101514	50757	294371
Cyclotella sp. (medium)	10935	0	3645	0	0	7290
Fragilaria sp.	0	0	0	0	3024	3024
TOTAL BACILLARIOPHYTA	10935	0	3645	0	3024	10314
Ankistrodesmus sp.	0	414	0	0	0	0
Chlorella sp.	0	0	0	0	3878	3878
Oocystis sp.	5816	17449	11633	11633	0	5816
nannoflagellata	0	4658	5480	2740	4658	5206
TOTAL CHLOROPHYTA	5816	22521	17113	14373	8536	14900
Cryptomonas sp.	0	0	10961	0	0	0
Rhodomonas s p.	6825	1706	5971	0	853	2559
TOTAL CRYPTOPHYTA	6825	1706	16932	0	853	2559